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Shim et al.

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(54) **THIN FILM TRANSISTOR SUBSTRATE AND METHOD FOR MANUFACTURING THE SAME AND ORGANIC LIGHT EMITTING DEVICE USING THE SAME**

H01L 29/78633 (2013.01); *H01L 29/78648* (2013.01); *H01L 51/50* (2013.01)

(58) **Field of Classification Search**
CPC . H01L 21/775; H01L 27/12; H01L 29/66757; H01L 29/66765; H01L 29/78621
USPC 438/149
See application file for complete search history.

(71) Applicant: **LG Display Co., Ltd.**, Seoul (KR)

(72) Inventors: **Jong Sik Shim**, Seoul (KR); **Woo Jin Nam**, Goyang-si (KR); **Hong Jae Shin**, Seoul (KR); **Min Kyu Chang**, Seoul (KR)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,255,131 B1 7/2001 Mori et al.
7,687,807 B2* 3/2010 Koo et al. 257/59

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1524702 A2 4/2005
KR 10-2011-0069908 A 6/2011

(Continued)

OTHER PUBLICATIONS

Taiwanese Office Action, Taiwanese Application No. 101144375, Jan. 15, 2015, 15 pages.

Primary Examiner — Quoc Hoang

(74) *Attorney, Agent, or Firm* — Fenwick & West LLP

(73) Assignee: **LG Display Co., Ltd.**, Seoul (KR)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H01L 21/00 (2006.01)
H01L 29/66 (2006.01)

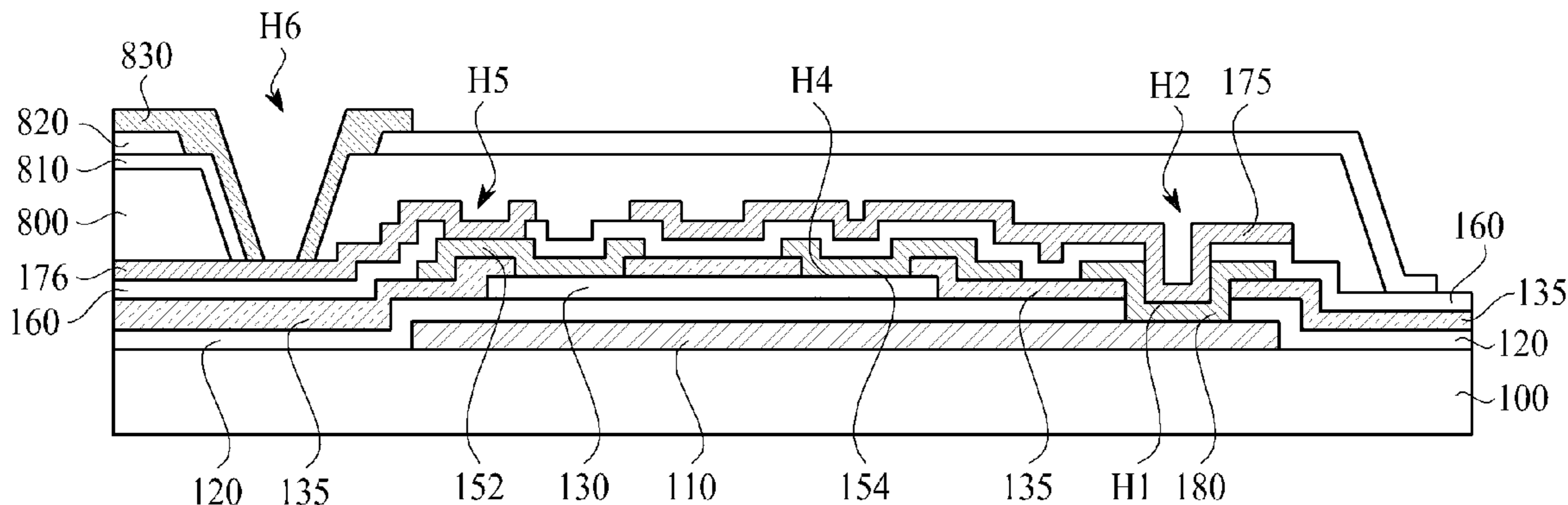
(Continued)

(52) **U.S. Cl.**
CPC *H01L 29/66969* (2013.01); *H01L 29/41733* (2013.01); *H01L 29/66742* (2013.01); *H01L 29/786* (2013.01); *H01L 29/7869* (2013.01);

(57) **ABSTRACT**

Disclosed is a thin film transistor substrate which facilitates to improve output and transfer characteristics of thin film transistor, wherein the thin film transistor substrate comprises a thin film transistor comprising a lower gate electrode on a substrate, an active layer on the lower gate electrode, source and drain electrodes on the active layer, and an upper gate electrode on the source electrode, drain electrode and active layer, the upper gate electrode for covering a channel region defined by the source and drain electrodes; and a contact portion for electrically connecting the lower gate electrode with the upper gate electrode.

17 Claims, 15 Drawing Sheets



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- (51) **Int. Cl.**
H01L 29/786 (2006.01)
H01L 51/50 (2006.01)
H01L 29/417 (2006.01)
- 2011/0108846 A1 5/2011 Choi et al.
2011/0136301 A1 6/2011 Yamazaki et al.
2011/0240986 A1 10/2011 Tsai et al.
2011/0284852 A1 11/2011 Kim et al.
2012/0007084 A1 1/2012 Park et al.
2012/0104385 A1 5/2012 Godo et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0012097 A1 1/2005 Yamazaki
2005/0082530 A1 4/2005 Koo et al.
2007/0085938 A1* 4/2007 Yamazaki et al. 349/43
2007/0290227 A1 12/2007 Liang et al.
2011/0084278 A1 4/2011 Cho et al.

FOREIGN PATENT DOCUMENTS

TW 200511589 A 3/2005
TW 200801672 A 1/2008
TW 201117370 A 5/2011

* cited by examiner

FIG. 1A

[Related Art]

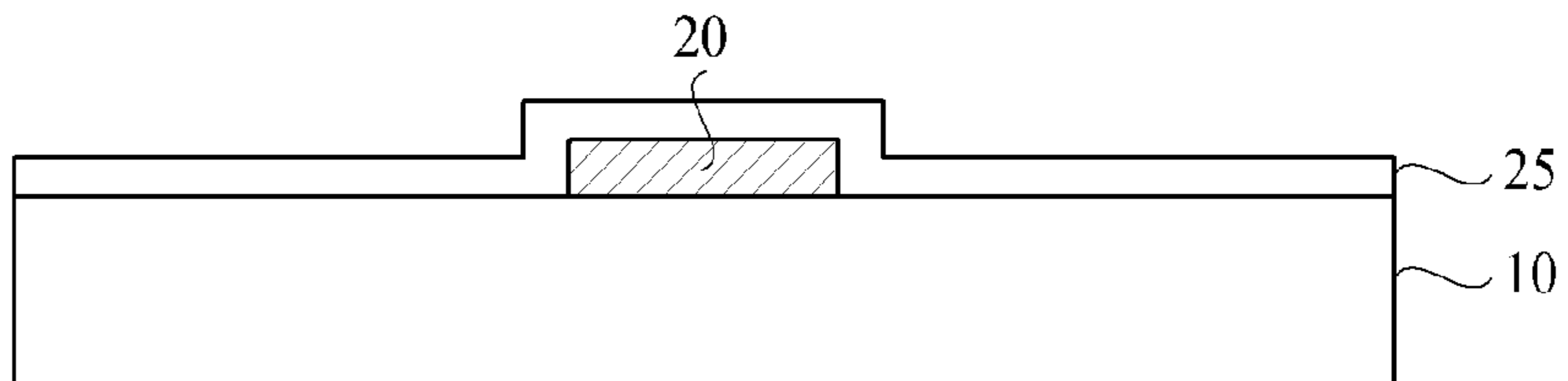


FIG. 1B

[Related Art]

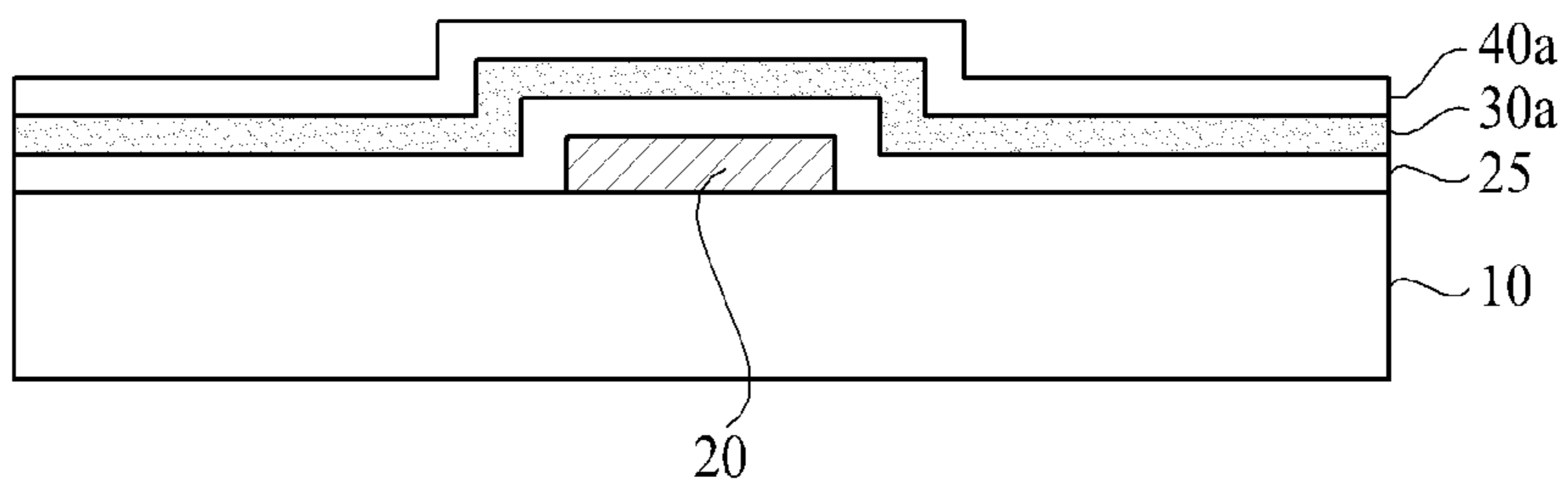


FIG. 1C

[Related Art]

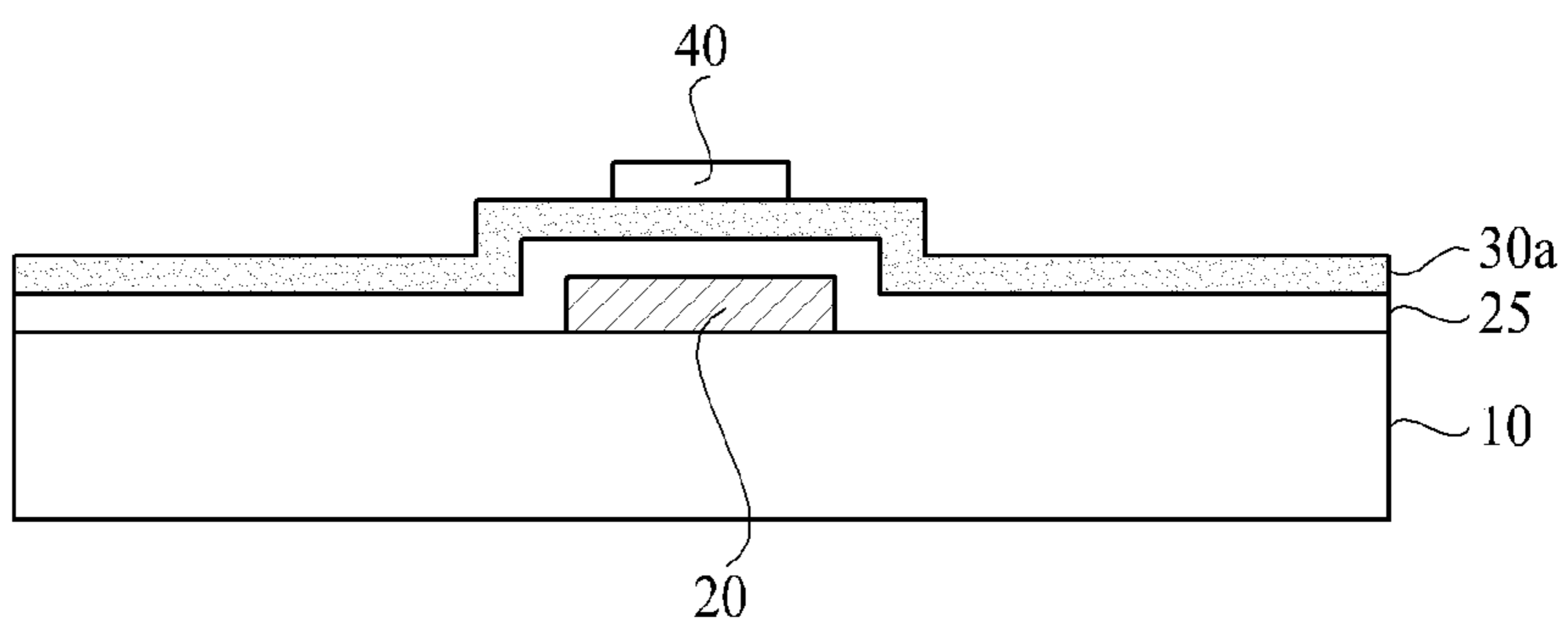


FIG. 1D

[Related Art]

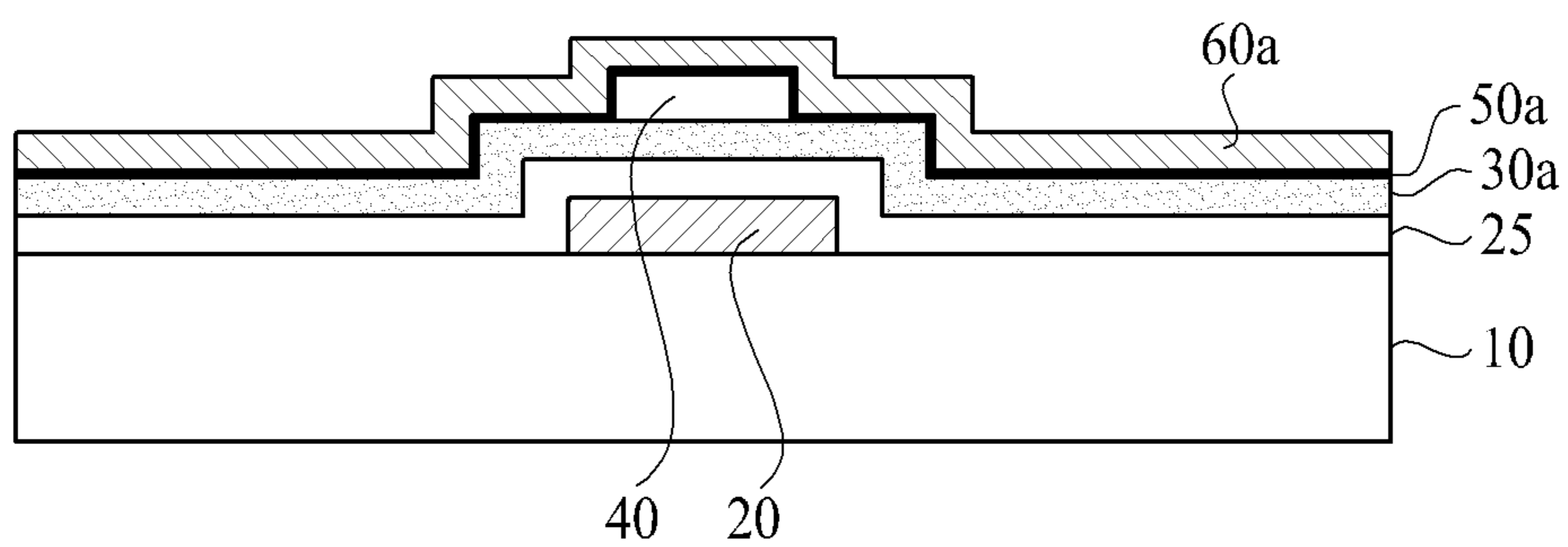


FIG. 1E

[Related Art]

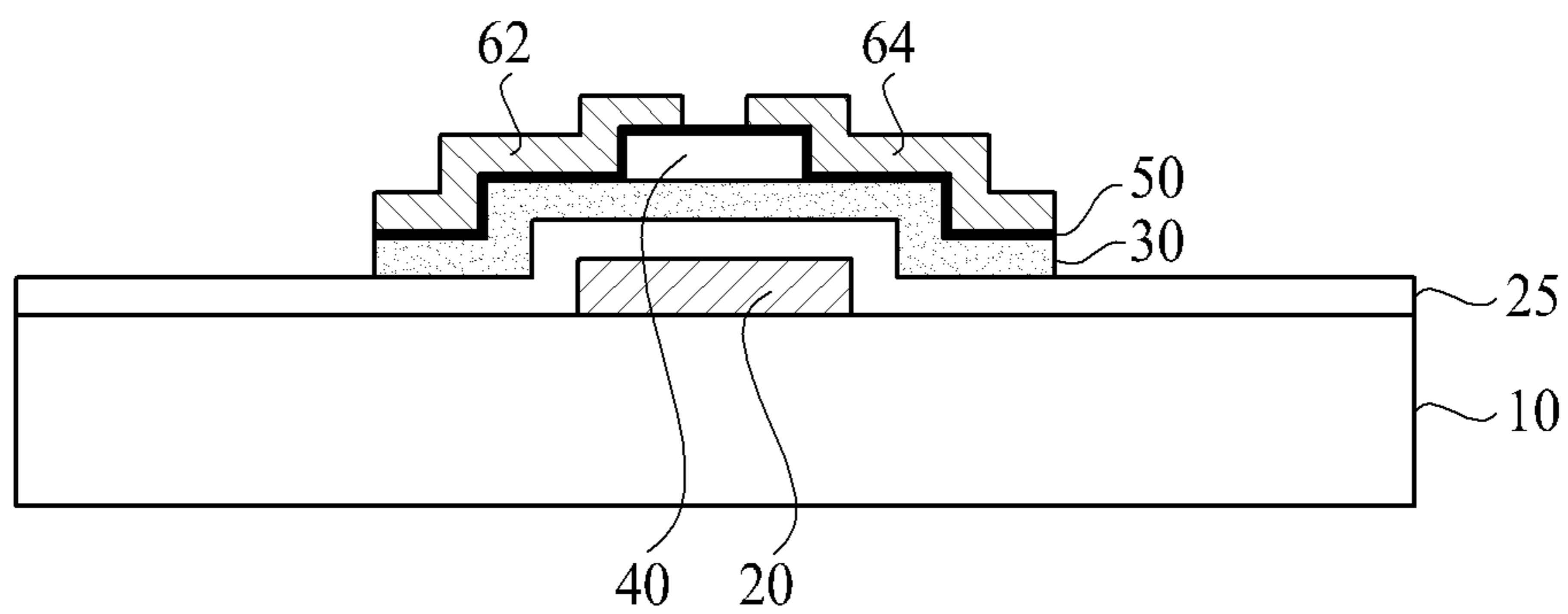


FIG. 2A

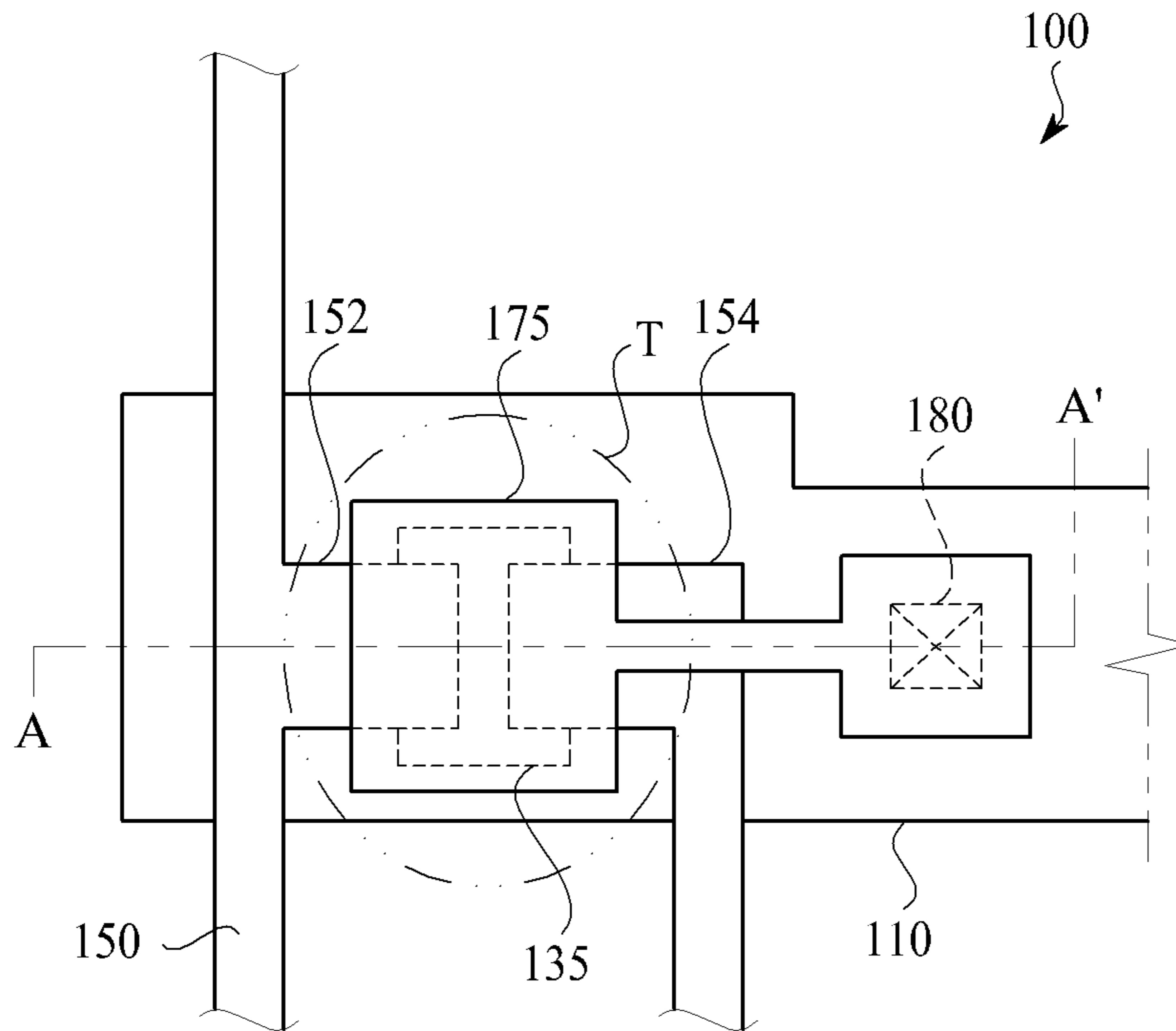


FIG. 2B

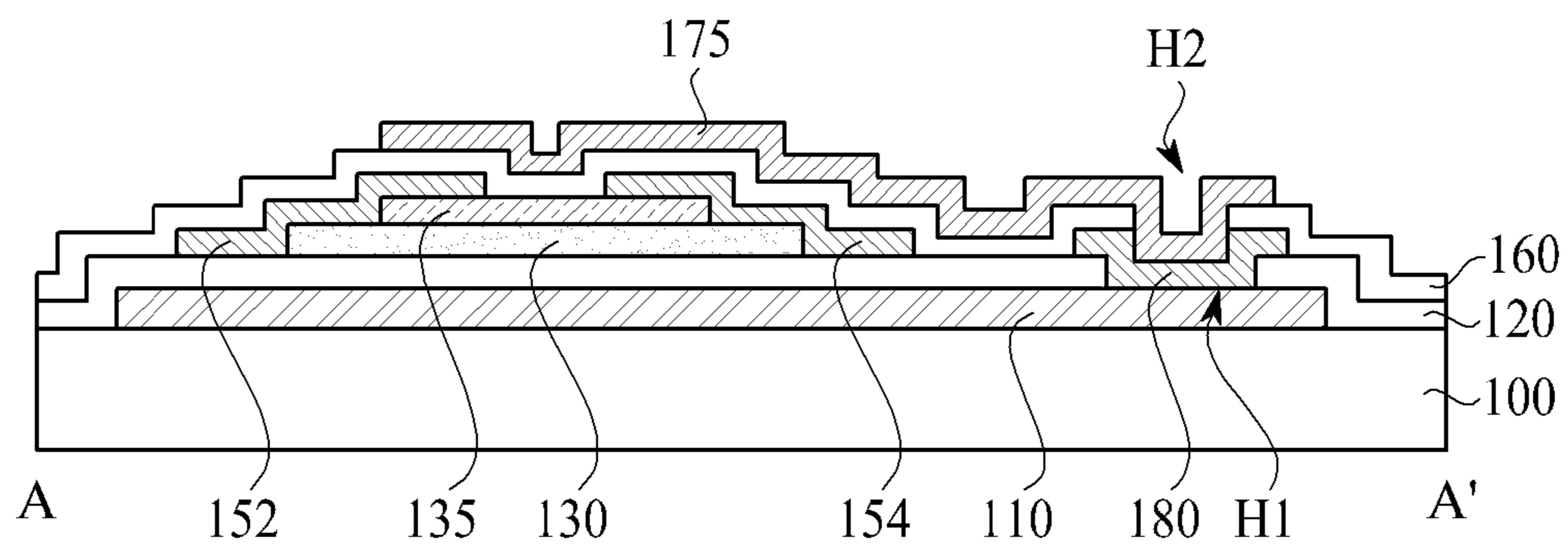


FIG. 3A

SINGLE GATE ELECTRODE THIN FILM TRANSISTOR CHARACTERISTICS

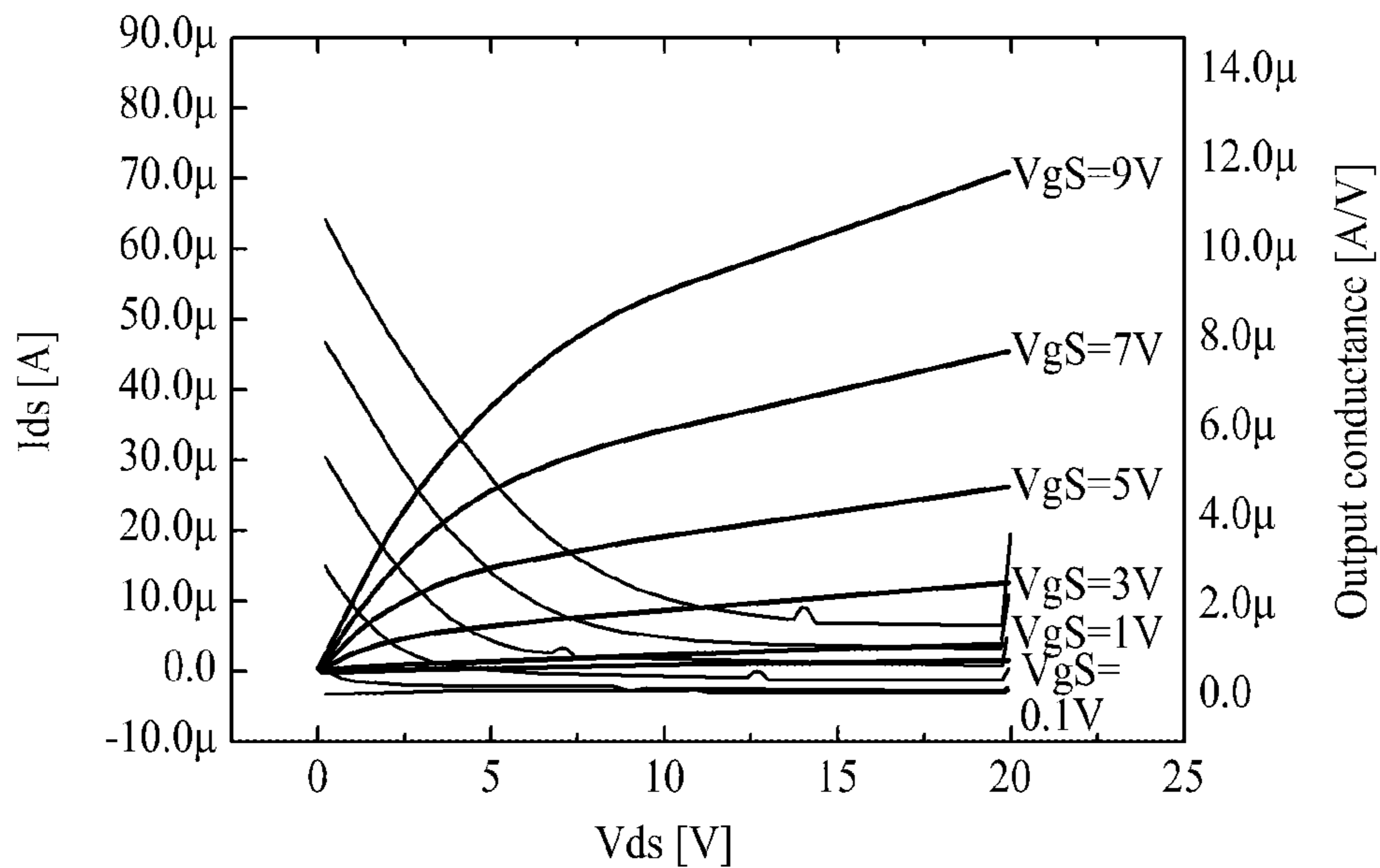


FIG. 3B

DUAL GATE ELECTRODE THIN FILM TRANSISTOR CHARACTERISTICS

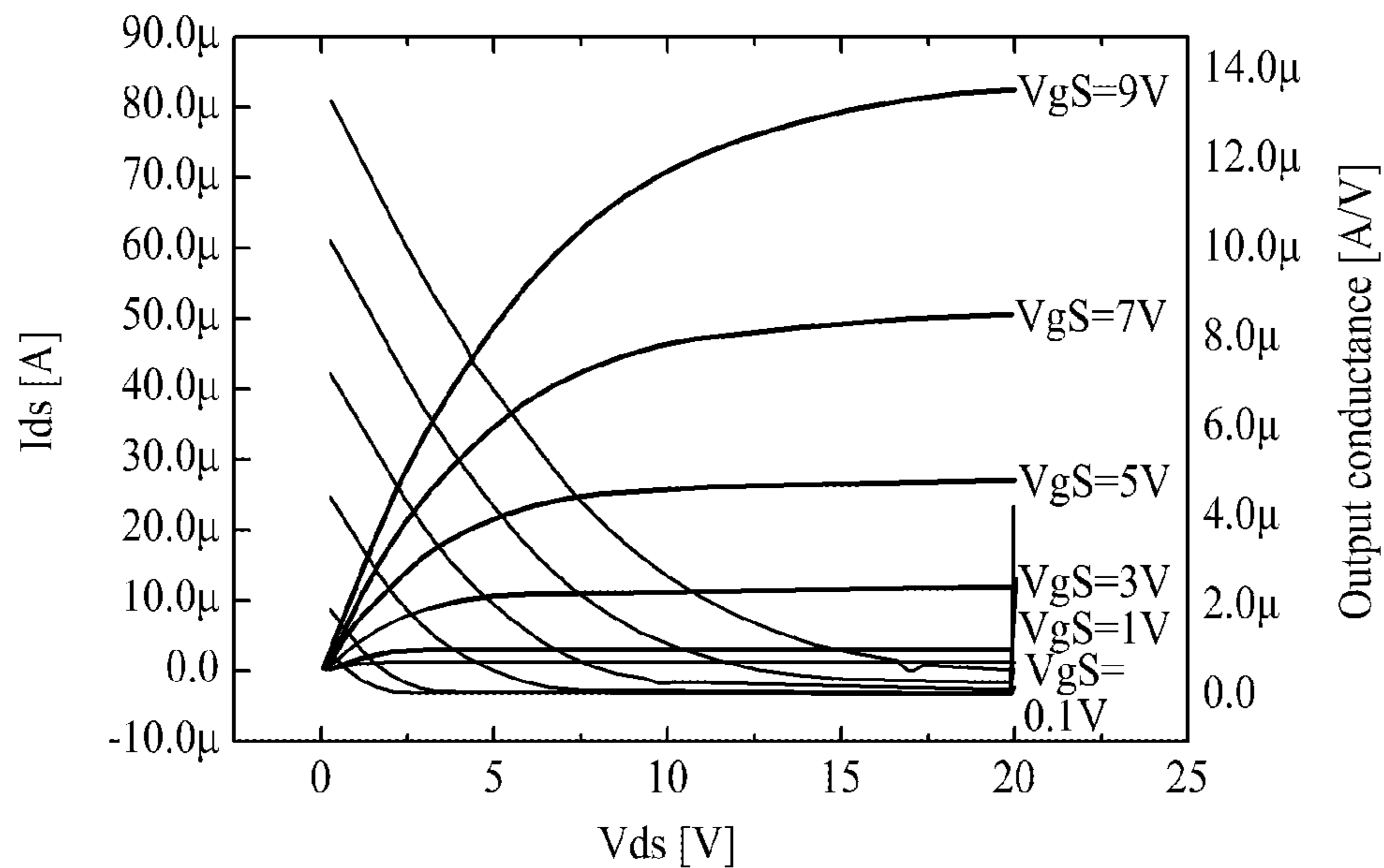


FIG. 4A

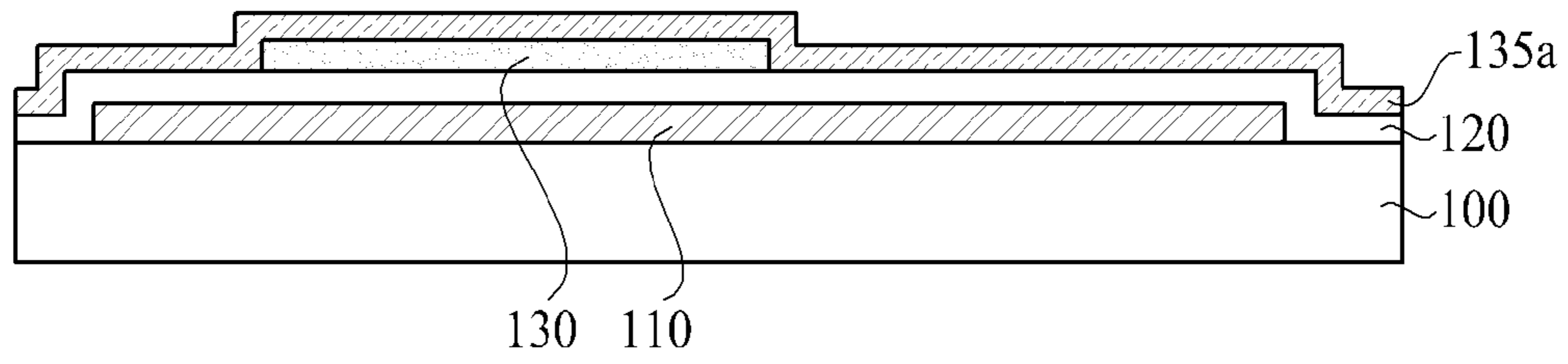


FIG. 4B

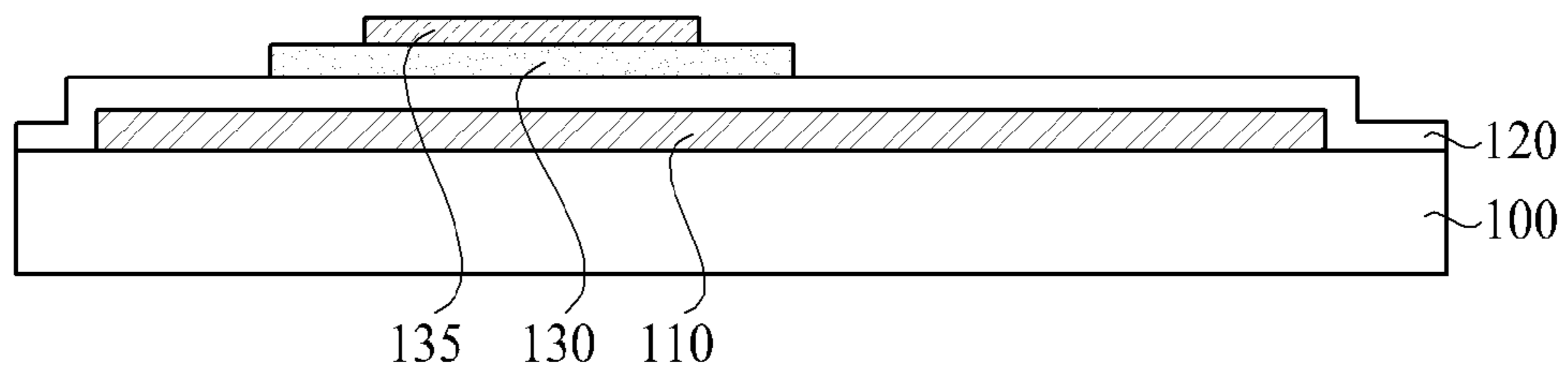


FIG. 4C

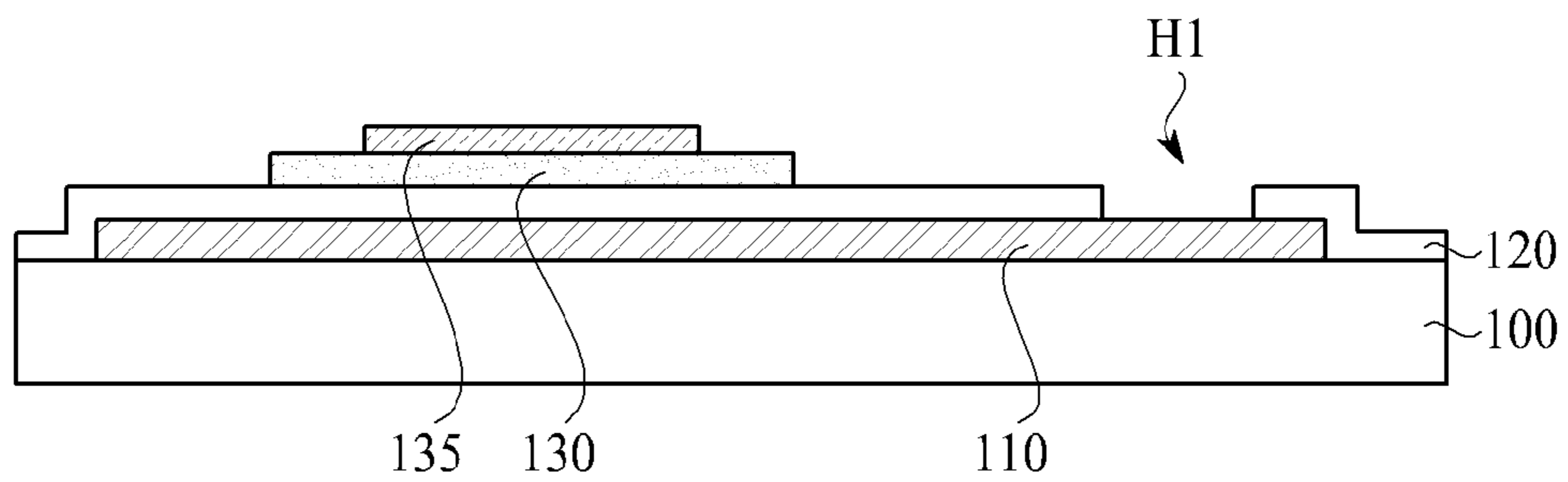


FIG. 4D

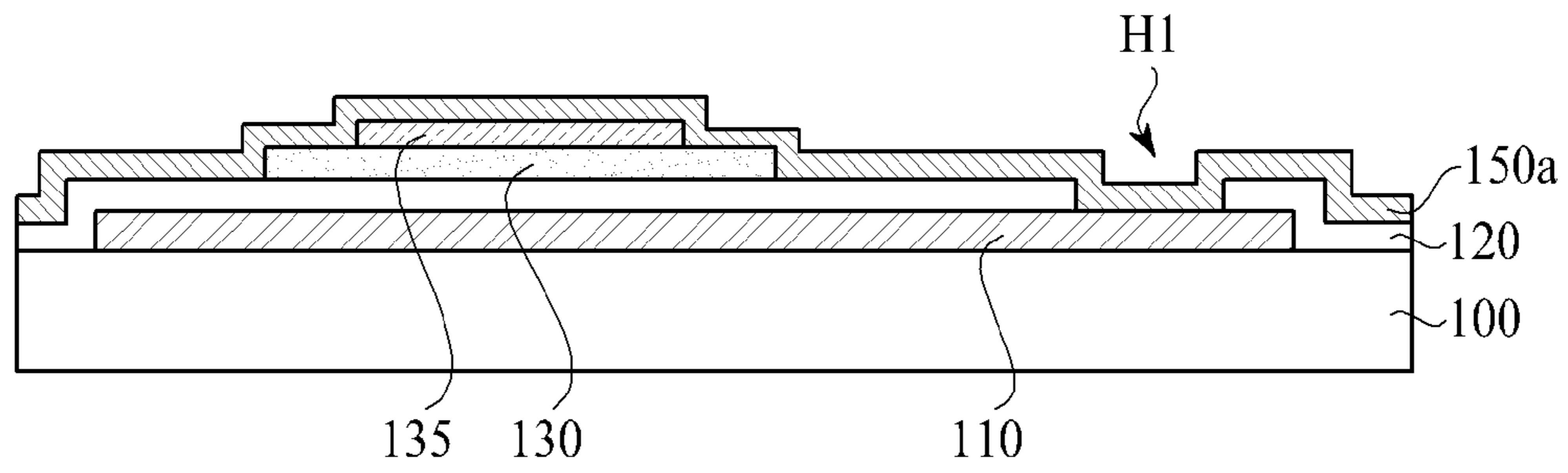


FIG. 4E

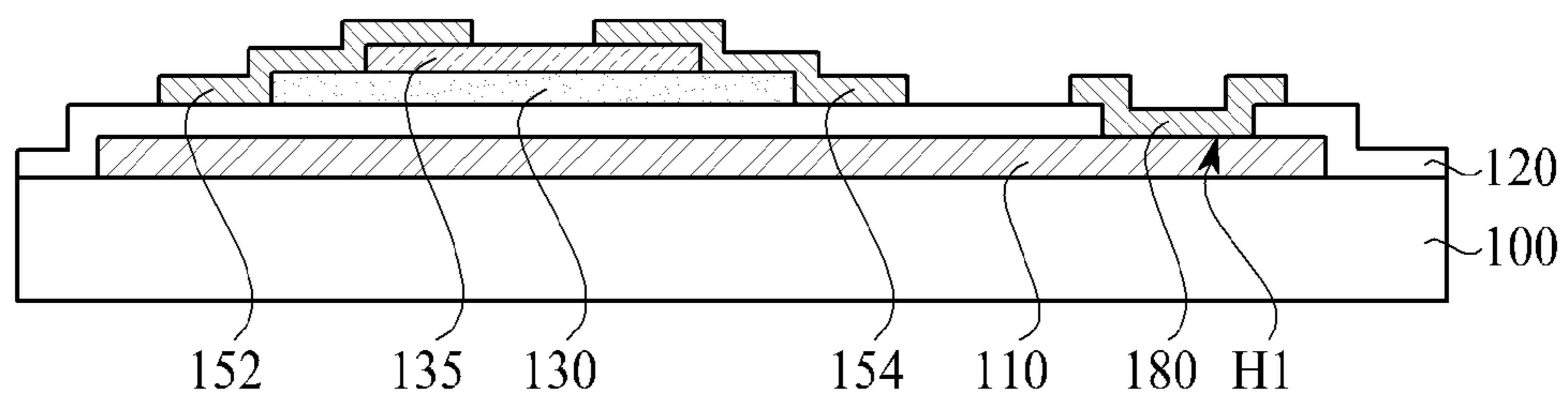


FIG. 4F

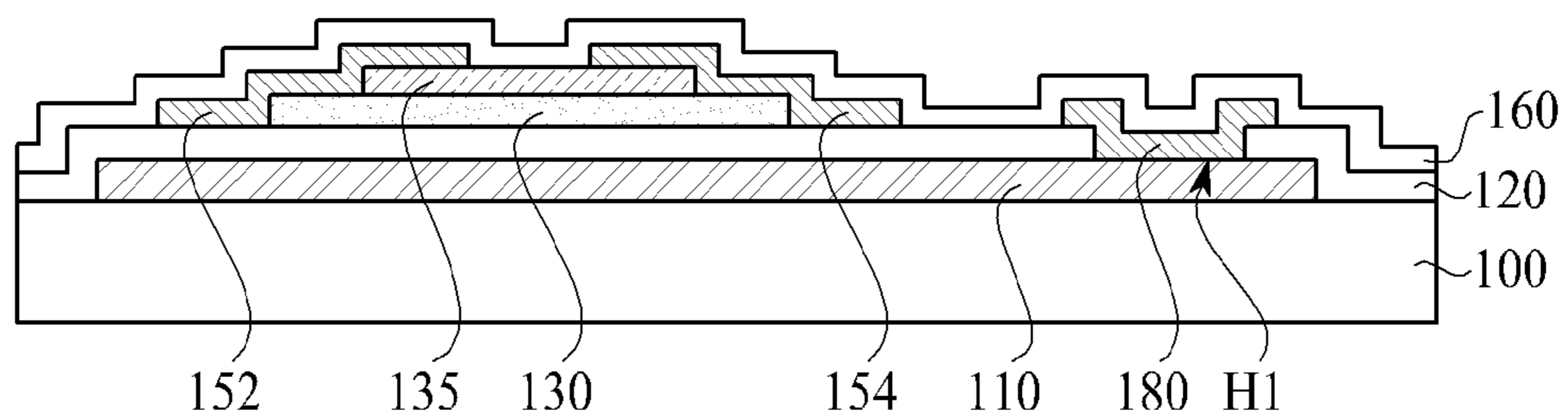


FIG. 4G

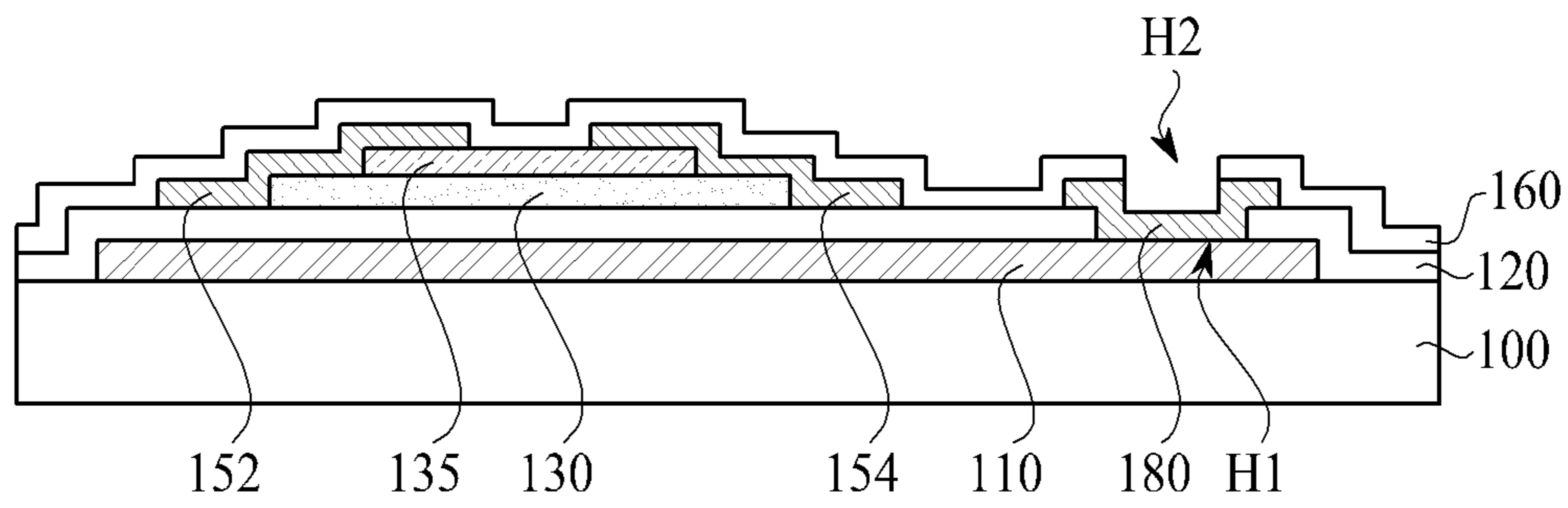


FIG. 4H

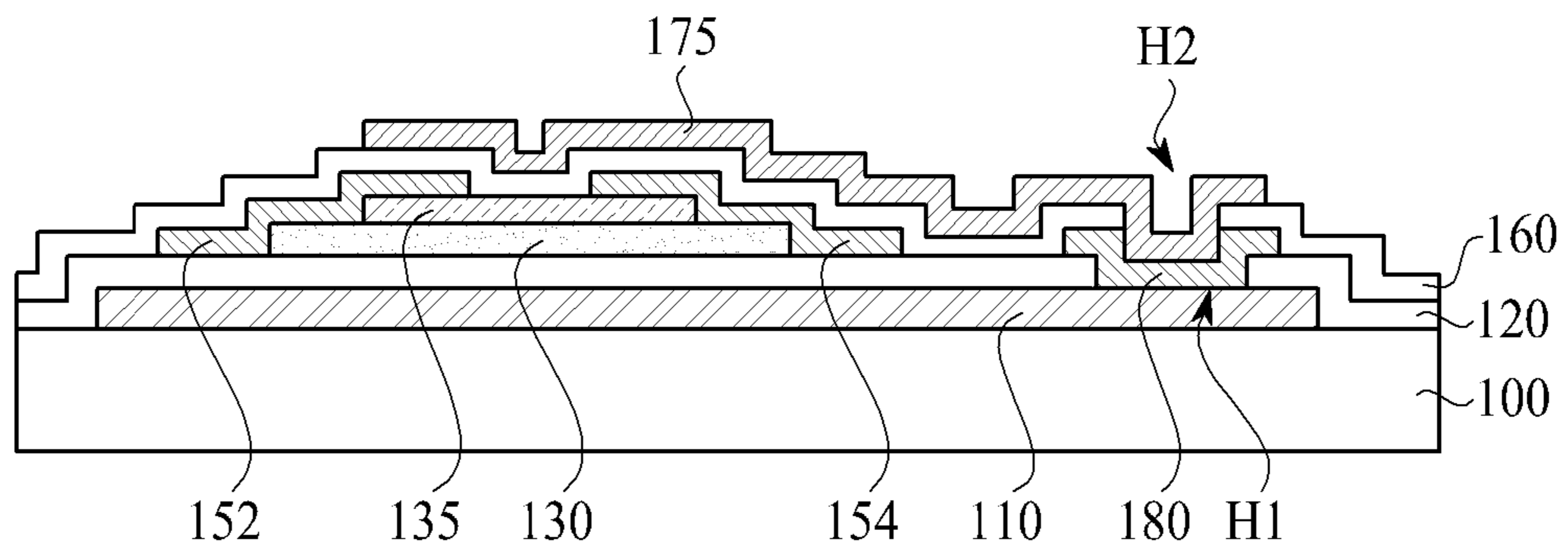


FIG. 5A

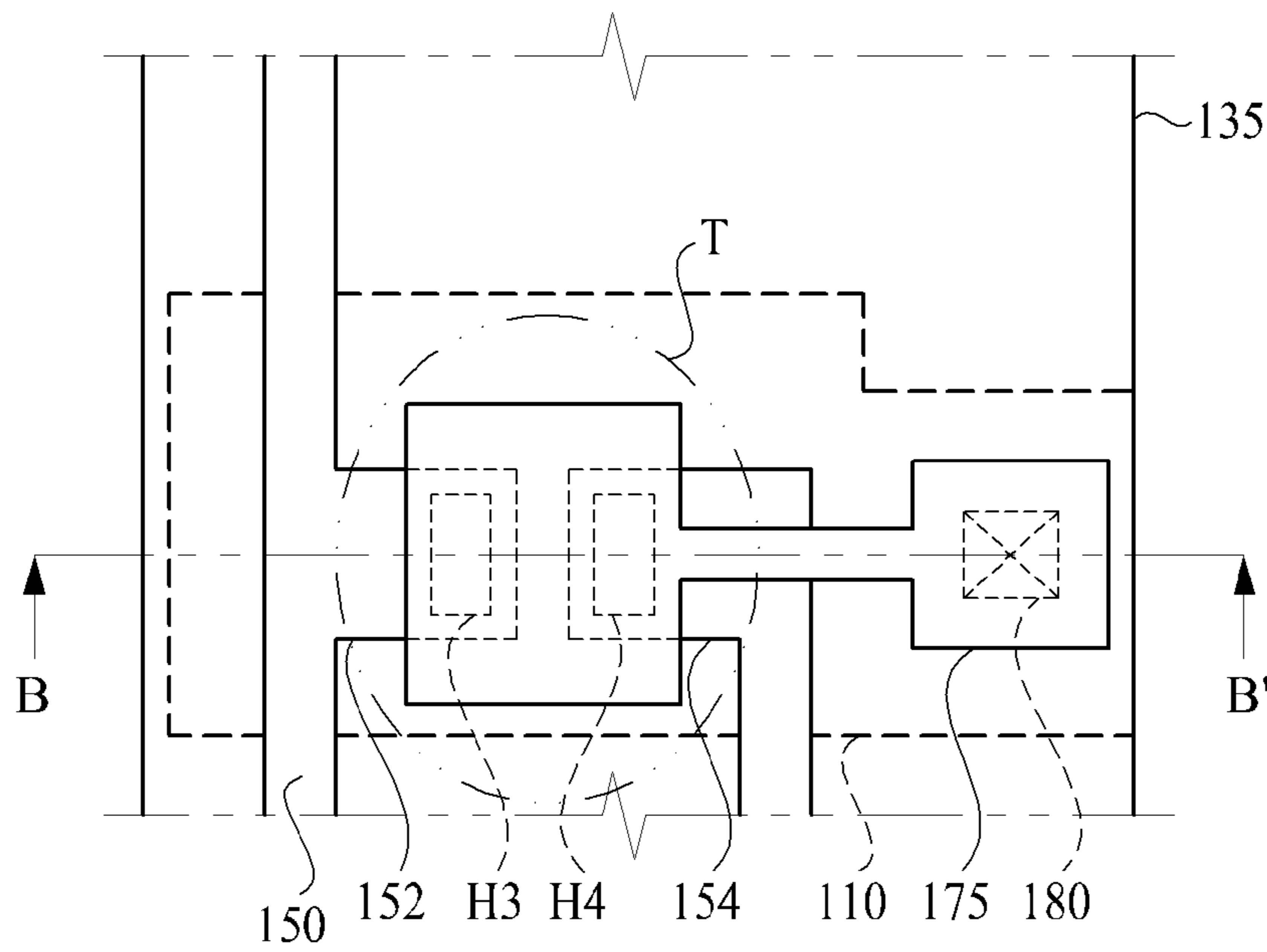


FIG. 5B

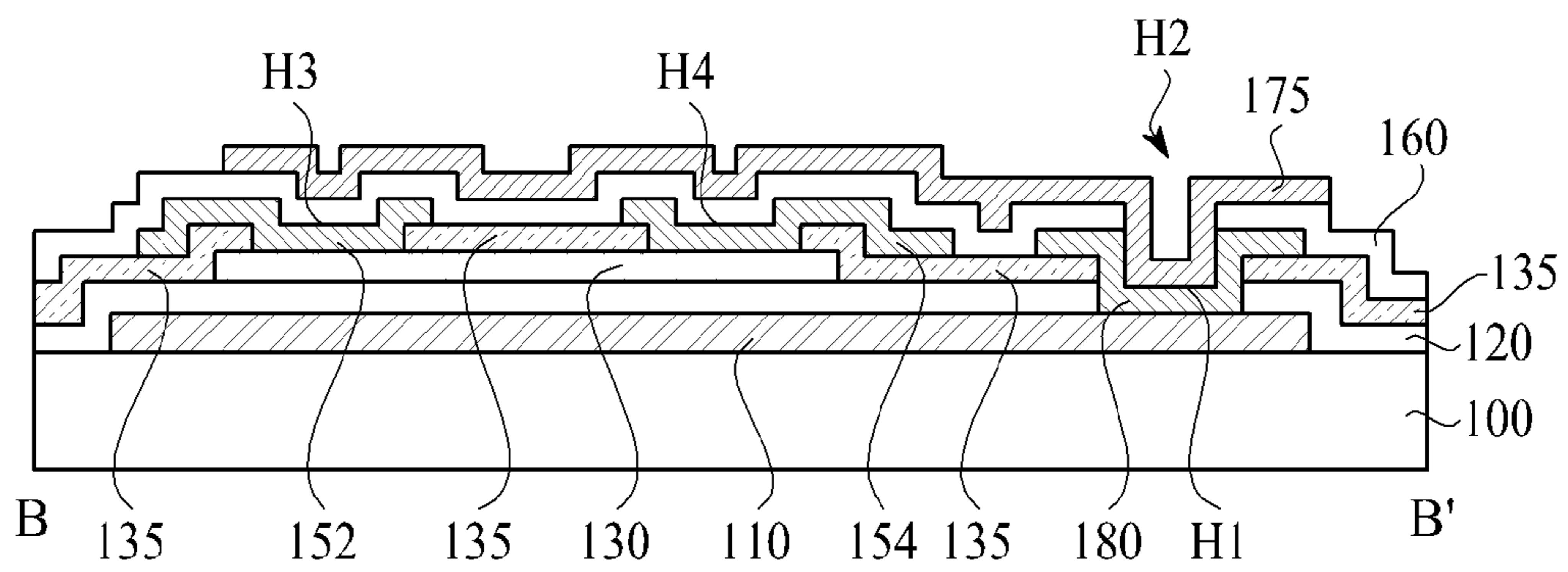


FIG. 6A

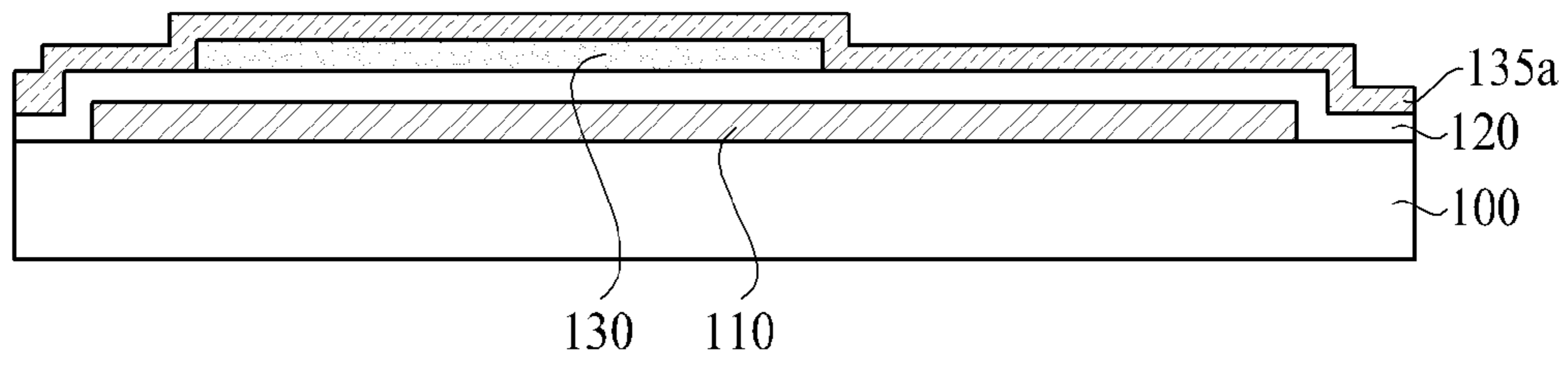


FIG. 6B

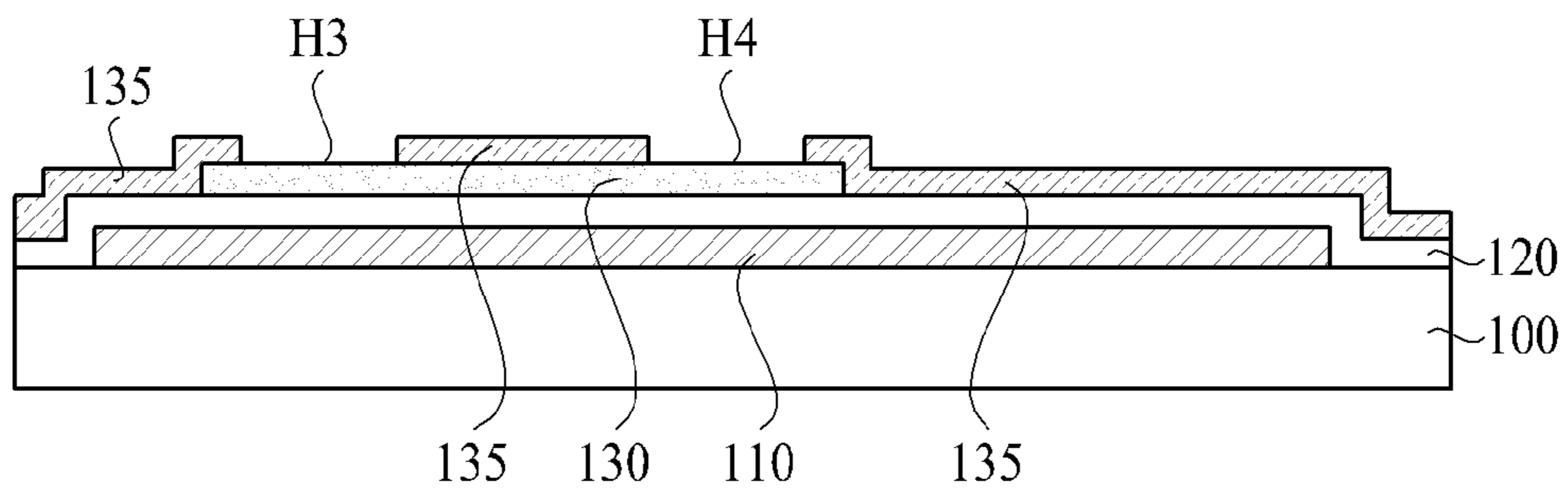


FIG. 6C

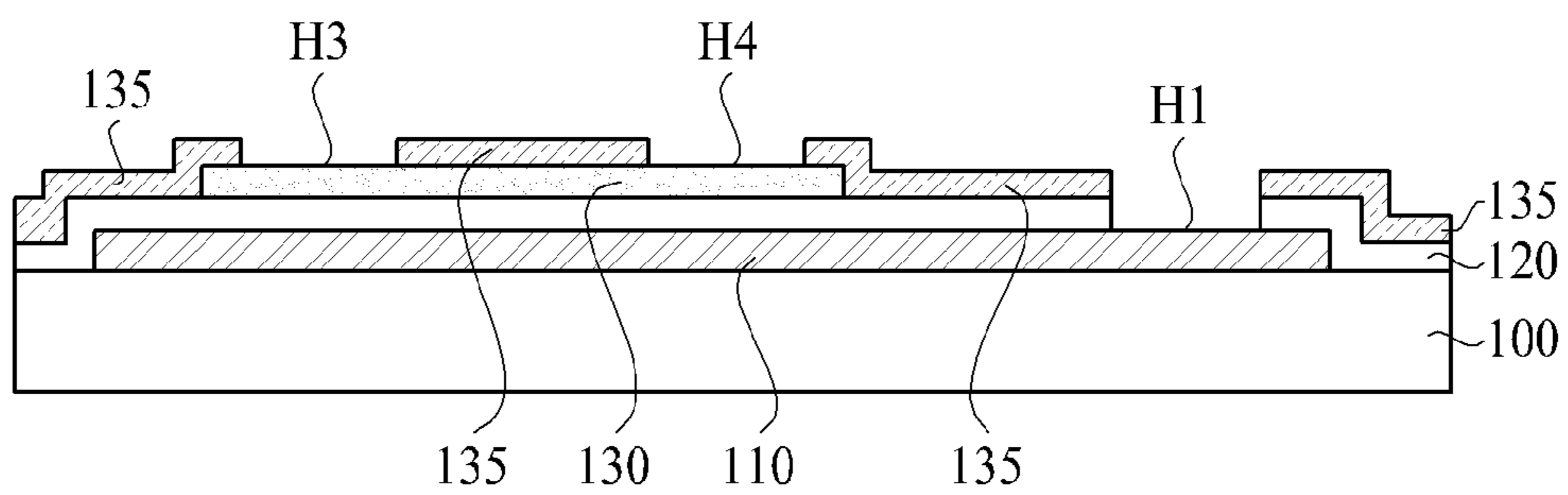


FIG. 6D

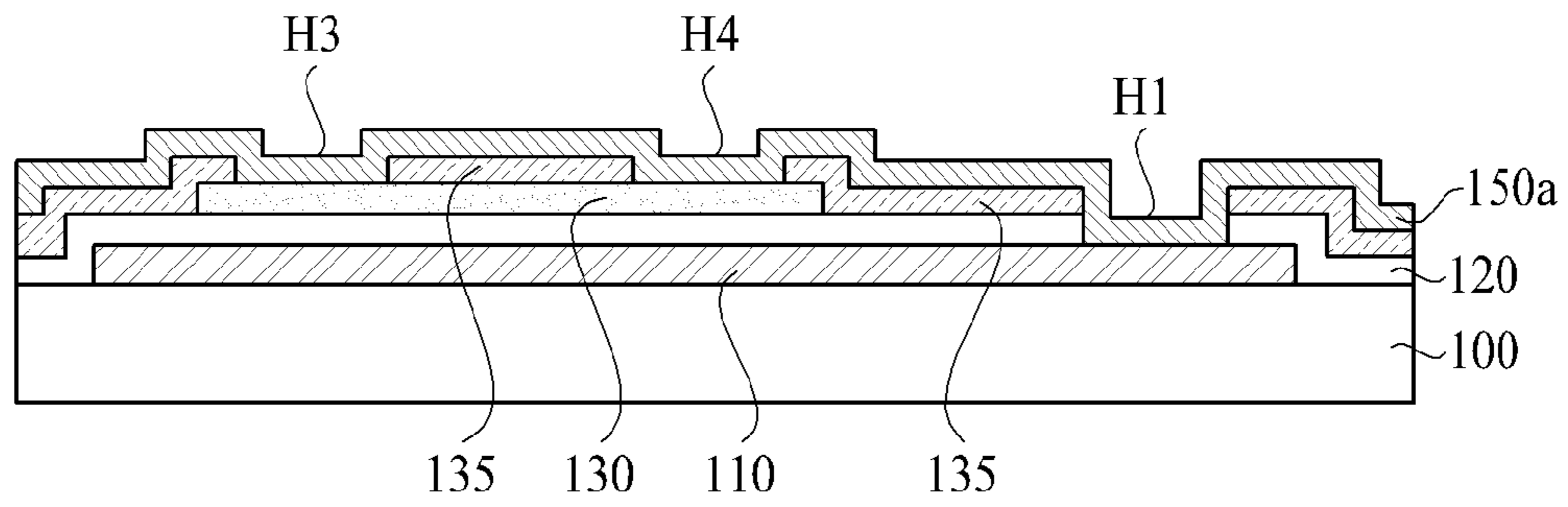


FIG. 6E

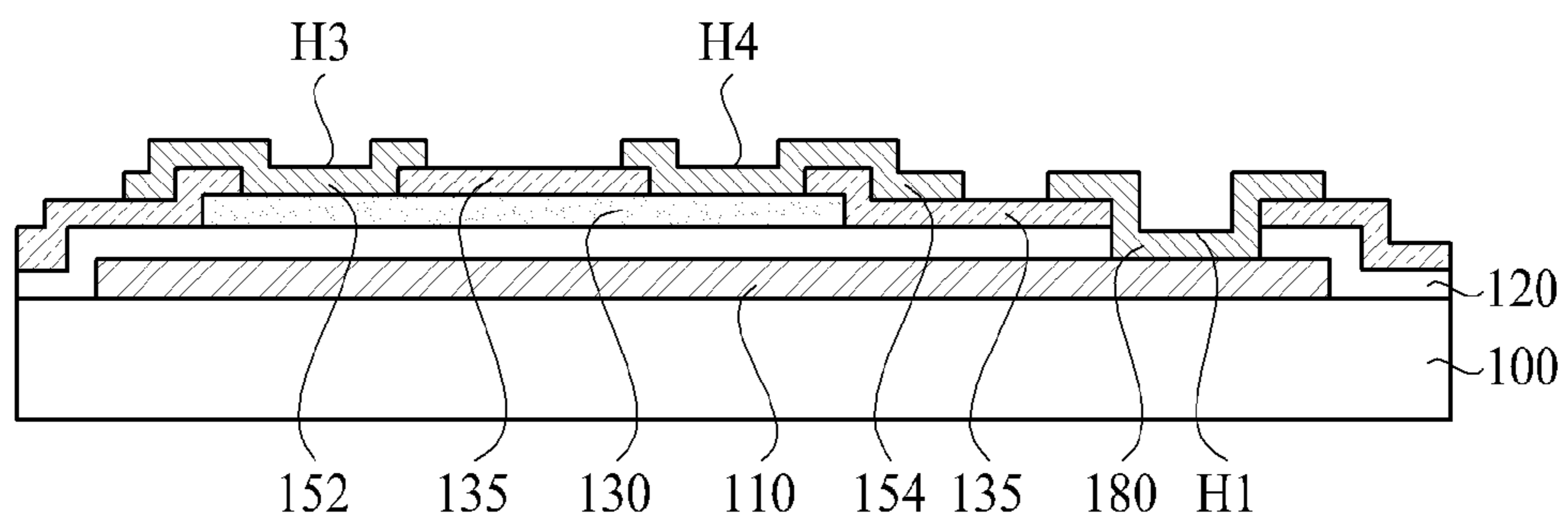


FIG. 6F

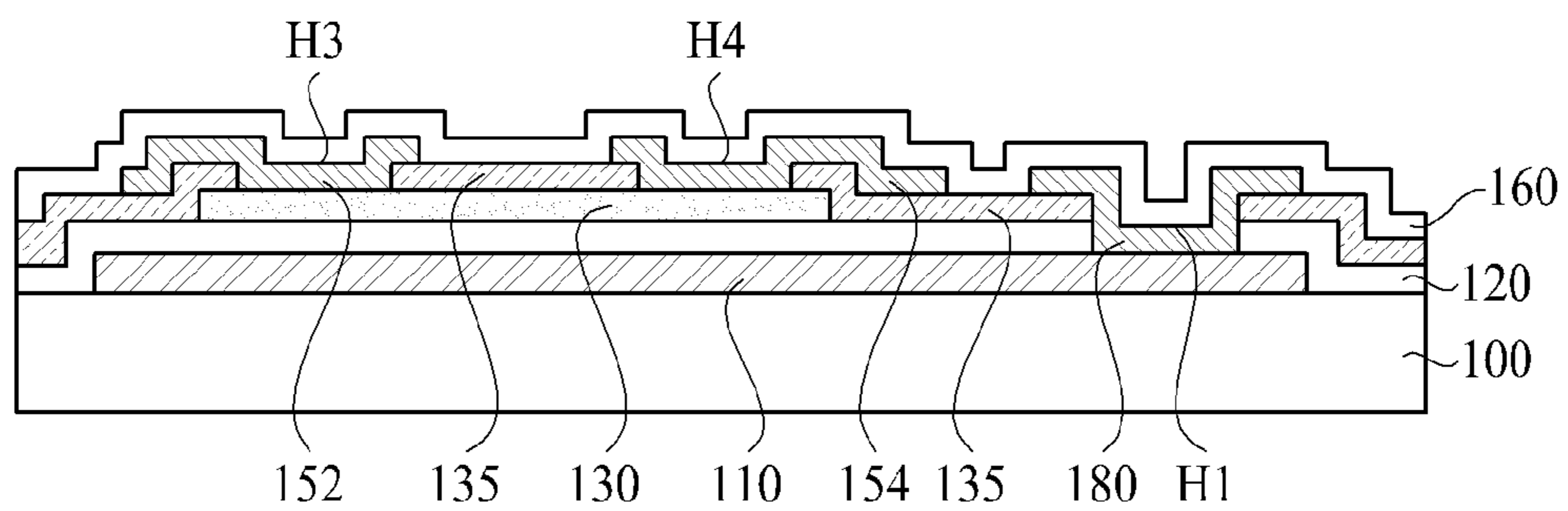


FIG. 6G

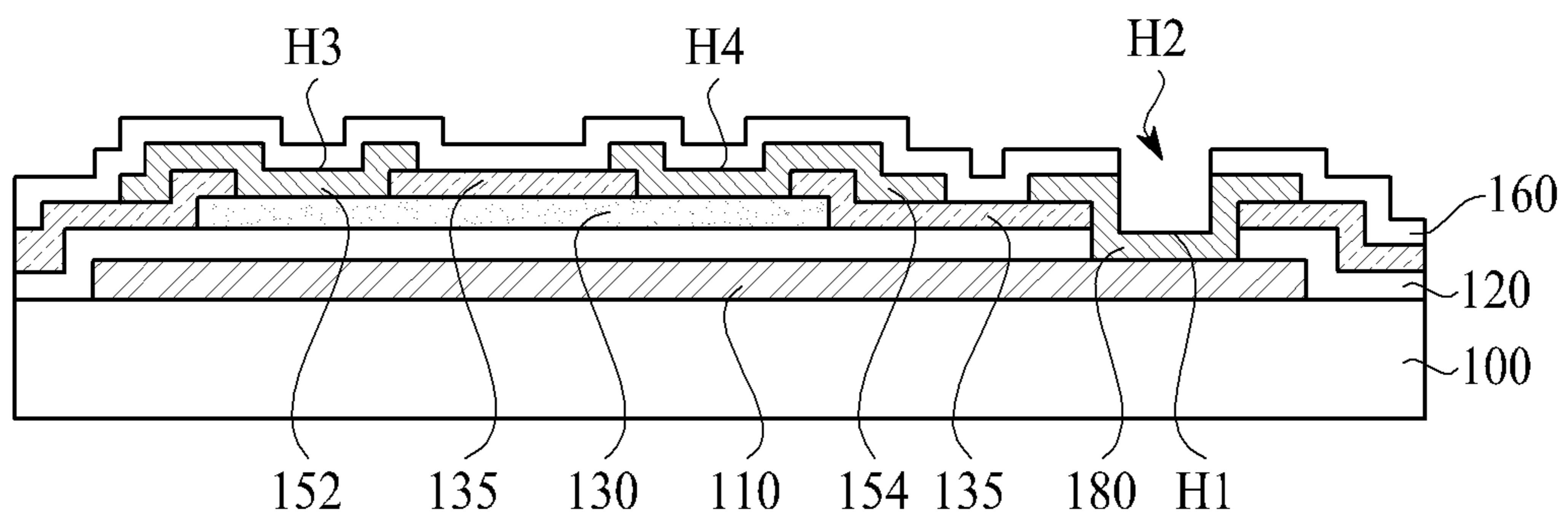


FIG. 6H

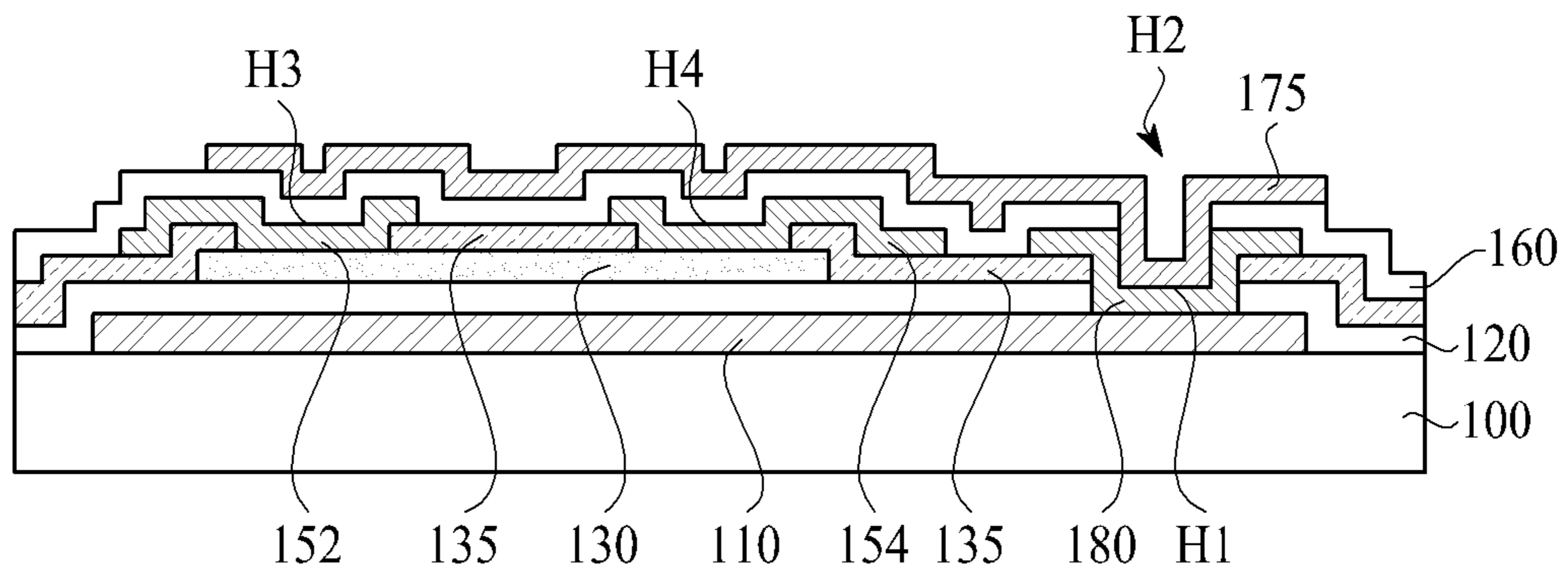


FIG. 7A

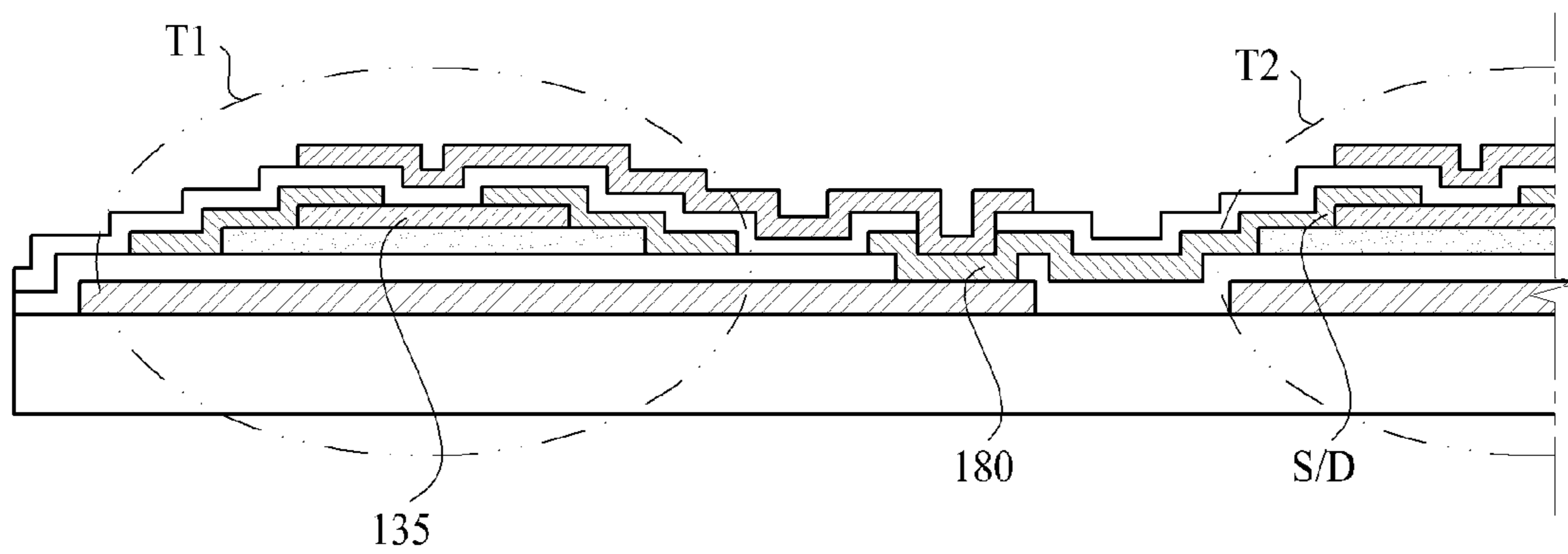


FIG. 7B

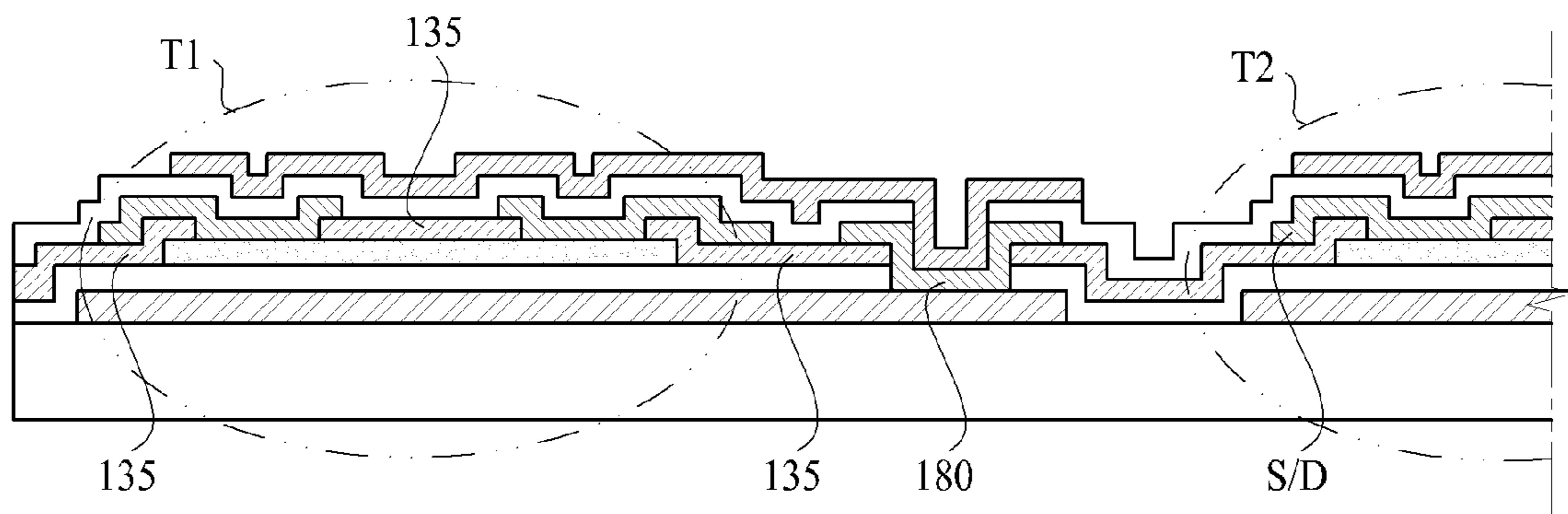


FIG. 8

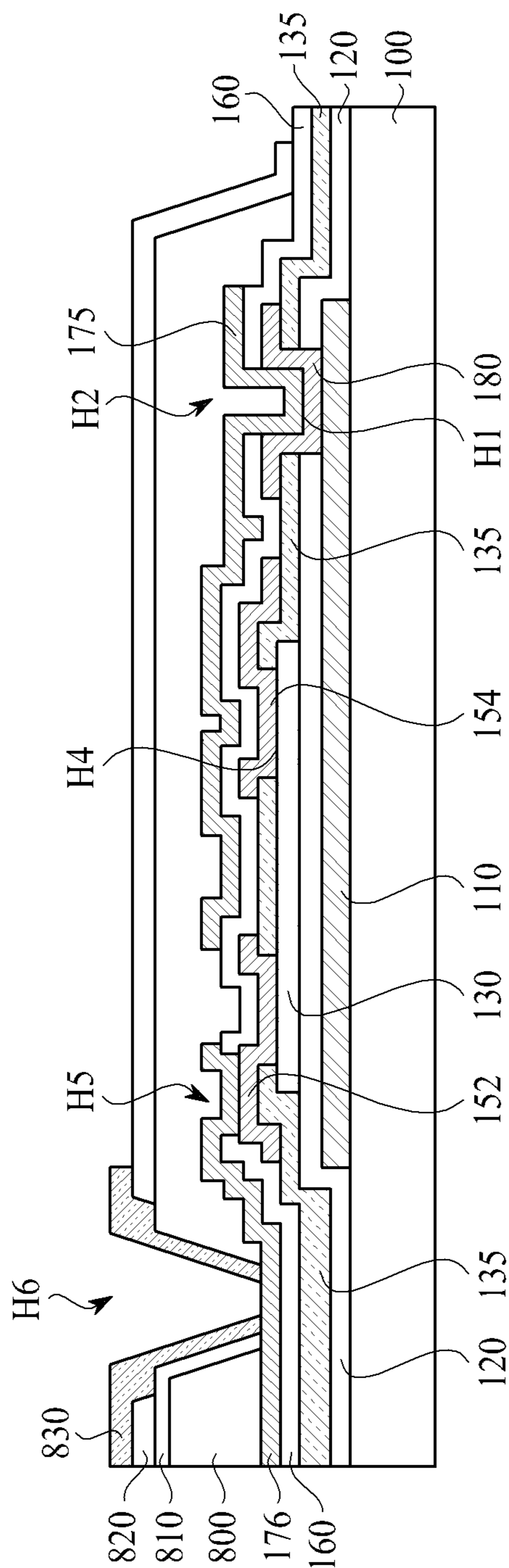


FIG. 9A

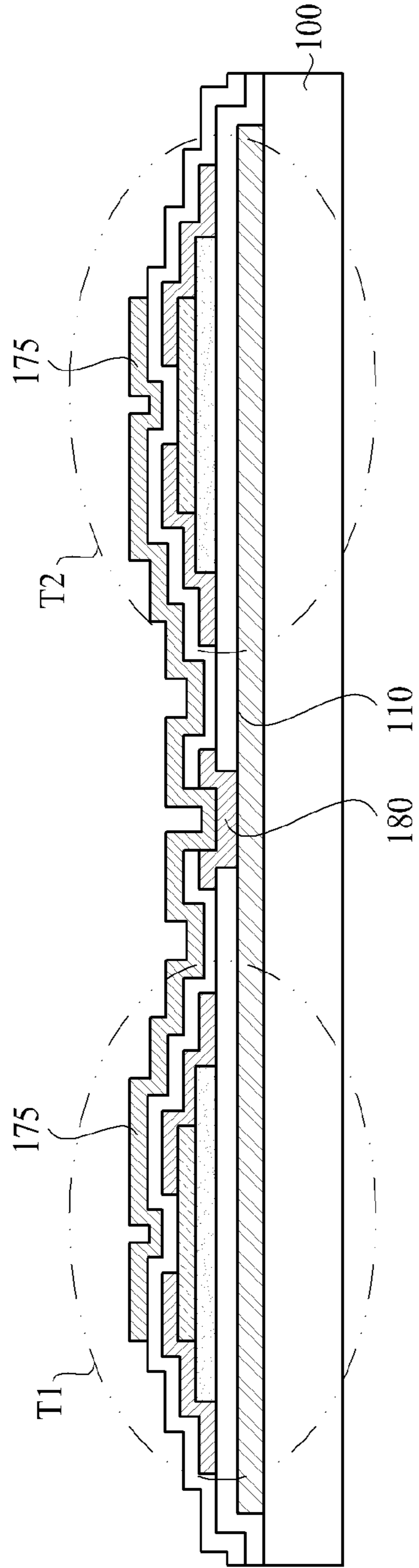


FIG. 9B

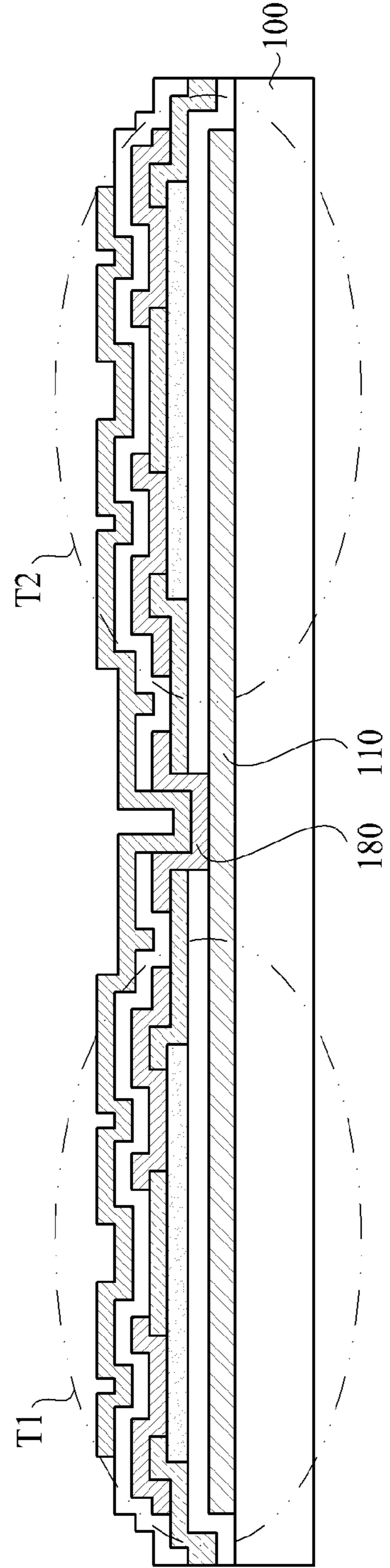
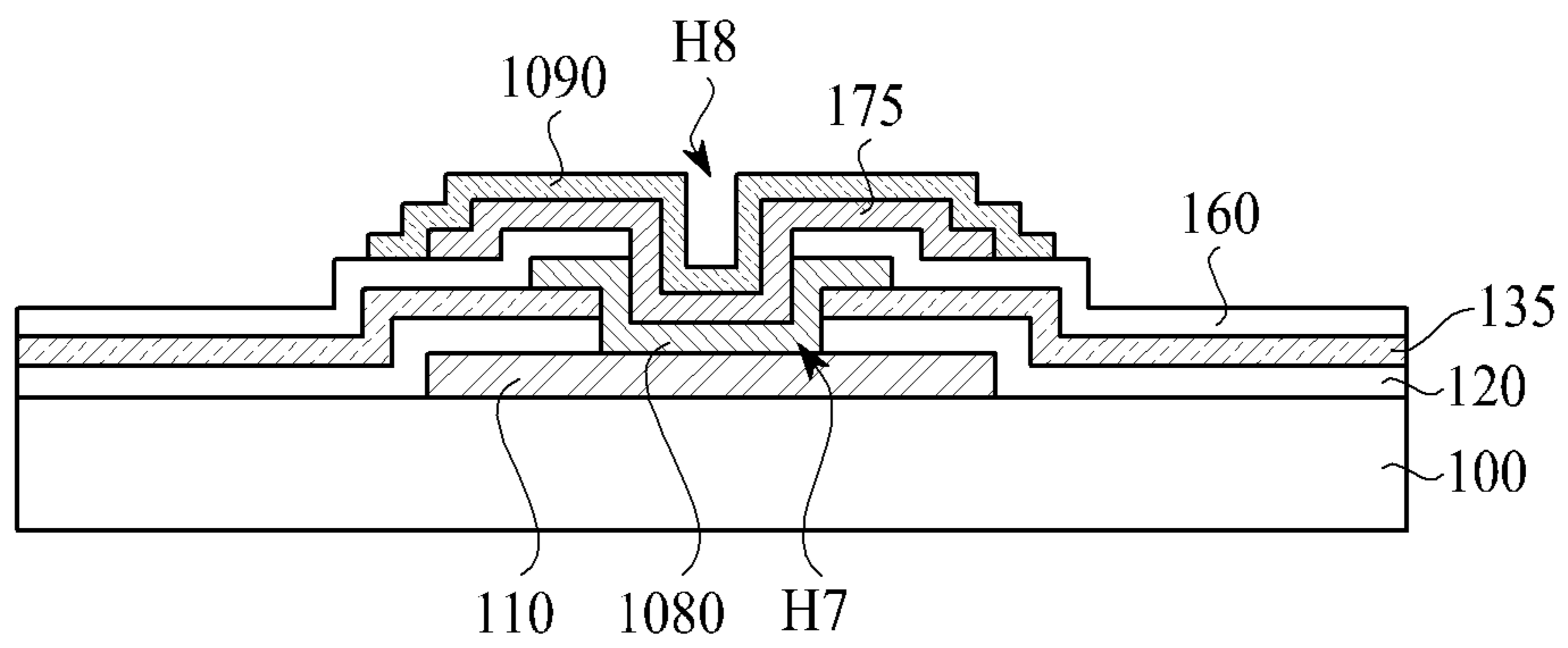


FIG. 10



**THIN FILM TRANSISTOR SUBSTRATE AND
METHOD FOR MANUFACTURING THE
SAME AND ORGANIC LIGHT EMITTING
DEVICE USING THE SAME**

CROSS REFERENCE TO RELATED
APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 13/685,572, titled "Thin Film Transistor Substrate and Method for Manufacturing the Same and Organic Light Emitting Device Using the Same" filed on Nov. 26, 2012, which claims the benefit of Korean Patent Application No. 10-2012-0088565 filed on Aug. 13, 2012, both of which are hereby incorporated by reference as if fully set forth herein.

BACKGROUND

1. Field of the Invention

The present invention relates to a display device, and more particularly, to a thin film transistor applied to a display device.

2. Discussion of the Related Art

A thin film transistor (TFT) is used as a switching element for controlling an operation of each pixel or a driving element for driving each pixel in a display device such as a liquid crystal display (LCD) or an organic light emitting device (OLED).

The thin film transistor includes a gate electrode, an active layer, and source/drain electrodes. Based on an arrangement of the electrodes, the thin film transistor may be classified into a staggered structure and a coplanar structure.

In case of the staggered structure, the gate electrode and the source/drain electrodes are vertically arranged with the active layer interposed therebetween. Meanwhile, in case of the coplanar structure, the gate electrode and the source/drain electrodes are arranged on the same plane.

According to a channel formation method, the thin film transistor of the staggered structure may be classified into a back channel etched (BCE) type and an etch stopper layer (ESL) type. In case of the ESL type, an etch stopper layer is formed on the active layer so that it is possible to prevent the active layer from being over-etched. Owing to this advantage, there is the increasing use of ESL type thin film transistor.

FIGS. 1A to 1E are cross sectional views illustrating a method for manufacturing an ESL type thin film transistor substrate.

First, as shown in FIG. 1A, a gate electrode **20** is formed on a substrate **10**, and then a gate insulating layer **25** is formed on an entire surface of the substrate **10** including the gate electrode **20**.

As shown in FIG. 1B, an active layer **30a** and an etch stopper layer **40a** are sequentially formed on the gate insulating layer **25**. After that, as shown in FIG. 1C, the etch stopper layer **40a** is patterned to thereby form a predetermined etch stopper **40**. The etch stopper **40** functions as a stopper for an etching process to be described later.

Then, as shown in FIG. 1D, an ohmic contact layer **50a** and a source/drain electrode layer **60a** are sequentially formed on the entire surface of the substrate **10** including the etch stopper **40**.

As shown in FIG. 1E, the source/drain electrode layer **60a** is patterned to form a source electrode **62** and a drain electrode **64**. Under the condition that the source/drain electrodes **62/64** are used as a mask, the ohmic contact layer **50a** and active layer **30a** positioned underneath the source/drain elec-

trodes **62/64** are etched to thereby form an ohmic contact layer **50** and active layer **30** with a predetermined pattern.

The etch stopper **40** is not formed at left and right sides of the source/drain electrodes **62/64**, whereby both the ohmic contact layer **50a** and active layer **30a** are etched together. However, since the etch stopper **40** is formed in a region between the source electrode **62** and the drain electrode **64**, only the ohmic contact layer **50a** is etched therein.

However, because the related art thin film transistor is formed in a single gate electrode structure with one gate electrode **20**, as shown in FIGS. 1A to 1E, it is difficult to achieve output saturation characteristics. In addition, there is a non-negligible gap between transfer curves according to voltages between source and drain of a thin film transistor within a subthreshold region, whereby problems of crosstalk or non-uniform luminance such as spots may occur on a screen. Especially, if the thin film transistor with the single gate electrode structure is applied to the organic light emitting device, a compensation capacity may be deteriorated.

Also, in case of the related art thin film transistor with the etch stopper **40**, the thin film transistor is inevitably increased in size due to an overlay rule in between each layer. Due to the increased size of thin film transistor, an overlap area between the gate electrode **20** and the source/drain electrodes **62/64** is increased in size, to thereby increase a capacitance of the thin film transistor.

SUMMARY

Accordingly, the present invention is directed to a thin film transistor substrate and a method for manufacturing the same that substantially obviates one or more problems due to limitations and disadvantages of the related art.

An aspect of the present invention is to provide a thin film transistor substrate which facilitates to improve output and transfer characteristics of thin film transistor, and a method for manufacturing the same.

Another aspect of the present invention is to provide a thin film transistor substrate which facilitates to restrict the increase of capacitance of a thin film transistor due to the increase of overlay rule.

Another aspect of the present invention is to provide an organic light emitting device using the above thin film transistor substrate.

Additional advantages and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objectives and other advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, there is provided a thin film transistor substrate comprising: a thin film transistor comprising a lower gate electrode on a substrate, an active layer on the lower gate electrode, source and drain electrodes on the active layer, and an upper gate electrode on the source electrode, drain electrode and active layer, the upper gate electrode for covering a channel region defined by the source and drain electrodes; and a contact portion for electrically connecting the lower gate electrode with the upper gate electrode.

In another aspect of the present invention, there is provided a method for manufacturing a thin film transistor substrate comprising: sequentially forming a lower gate electrode, a gate insulating layer and an active layer on a substrate; form-

ing a first contact hole by patterning the gate insulating layer so as to expose the lower gate electrode; forming a source/drain electrode layer on the active layer; forming a source electrode, a drain electrode and a contact portion by patterning the source/drain electrode layer, wherein the contact portion is in contact with the lower gate electrode through the first contact hole; forming a passivation layer on an entire surface of the substrate including the source electrode, drain electrode, and contact portion; forming a second contact hole by patterning the passivation layer to expose the contact portion; and forming an upper gate electrode on the passivation layer, wherein the upper gate electrode covers a channel region defined by the source electrode and the drain electrode, and the upper gate electrode is brought into contact with the contact portion through the second contact hole.

In another aspect of the present invention, there is provided a method for manufacturing a thin film transistor substrate comprising: sequentially forming a lower gate electrode, a gate insulating layer and an active layer on a substrate; forming an etch stopper layer on an entire surface of the substrate including the active layer; forming a first contact hole by patterning the gate insulating layer and the etch stopper layer so as to expose the lower gate electrode; forming a source/drain electrode layer on the etch stopper layer; forming a source electrode, a drain electrode and a contact portion by patterning the source/drain electrode layer, wherein the contact portion is brought into contact with the lower gate electrode through the first contact hole; forming a passivation layer on the entire surface of the substrate including the source electrode, the drain electrode and the contact portion; forming a second contact hole by patterning the passivation layer to expose the contact portion; and forming an upper gate electrode on the passivation layer, wherein the upper gate electrode covers a channel region defined by the source electrode and the drain electrode, and the upper gate electrode is brought into contact with the contact portion through the second contact hole.

In a further aspect of the present invention, there is provided an OLED comprising: a substrate; a first thin film transistor on the substrate; a second thin film transistor connected with the first thin film transistor; a first contact portion connected with the first thin film transistor and the second thin film transistor; and an organic light emitting diode connected with the first thin film transistor, wherein the first thin film transistor comprises: a lower gate electrode on the substrate; an active layer on the lower gate electrode; source and drain electrodes on the active layer; and an upper gate electrode on the source electrode, the drain electrode and the active layer, the upper gate electrode for covering a channel region defined by the source electrode and the drain electrode, wherein the first contact portion is formed as a single body with the source electrode or drain electrode of the second thin film transistor so as to electrically connect the lower gate electrode and the upper gate electrode with each other.

It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate

embodiment(s) of the invention and together with the description serve to explain the principle of the invention. In the drawings:

FIGS. 1A to 1E are cross sectional views illustrating a method for manufacturing an ESL type thin film transistor substrate;

FIG. 2A is a plane view illustrating a thin film transistor substrate according to the first embodiment of the present invention;

FIG. 2B is a cross sectional view along A-A' of FIG. 2A;

FIG. 3A is a graph illustrating characteristics of a thin film transistor according to the related art;

FIG. 3B is a graph illustrating characteristics of a thin film transistor according to the present invention;

FIGS. 4A to 4H are cross sectional views illustrating a method for manufacturing the thin film transistor substrate according to the first embodiment of the present invention;

FIG. 5A is a plane view illustrating a thin film transistor substrate according to the second embodiment of the present invention;

FIG. 5B is a cross sectional view along B-B' of FIG. 5A;

FIGS. 6A to 6H are cross sectional views illustrating a method for manufacturing the thin film transistor substrate according to the second embodiment of the present invention;

FIGS. 7A and 7B are cross sectional views of a thin film transistor substrate according to the first modified embodiment of the present invention;

FIG. 8 is a cross sectional view of a thin film transistor substrate according to the second modified embodiment of the present invention;

FIGS. 9A and 9B are cross sectional views of a thin film transistor substrate according to the third modified embodiment of the present invention; and

FIG. 10 is a cross sectional view of a storage capacitor according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the exemplary embodiments of the present invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

On explanation about the embodiments of the present invention, if it is mentioned that a first structure is positioned 'on or above' or 'under or below' a second structure, it should be understood that the first and second structures are brought into contact with each other, or a third structure is interposed between the first and second structures. However, if it is mentioned that a first structure is positioned 'directly on' or 'directly under' a second structure, it should be understood that the first and second structures are brought into contact with each other.

First Embodiment

Hereinafter, a thin film transistor substrate according to the first embodiment of the present invention and a method for manufacturing the same will be described with reference to FIGS. 2 and 3.

Thin Film Transistor Substrate

FIG. 2A is a plane view illustrating a thin film transistor substrate according to the first embodiment of the present invention. FIG. 2B is a cross sectional view along A-A' of FIG. 2A.

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First, the thin film transistor substrate according to the first embodiment of the present invention will be described with reference to FIG. 2A.

As shown in FIG. 2A, a thin film transistor (T) and a contact portion **180** are formed on the thin film transistor substrate **100**, wherein the thin film transistor (T) functions as a switching element for controlling an operation of each pixel, or a driving element for driving each pixel.

The thin film transistor (T) includes a lower gate electrode **110**, an etch stopper layer **135**, a source electrode **152**, a drain electrode **154**, and an upper gate electrode **175**.

The lower gate electrode **110** is formed on the thin film transistor substrate **100**. The lower gate electrode **110** is electrically connected with the upper gate electrode **175** through the contact portion **180**. The lower gate electrode **110** may be diverged from a gate line (not shown).

The etch stopper layer **135** is formed between the source electrode **152** and the drain electrode **154**. The etch stopper layer **135** prevents an active layer (not shown) formed thereunder from being over-etched.

The source electrode **152** is connected with a data line **150**, and more particularly, the source electrode **152** may be diverged from the data line **150**. The drain electrode **154** is formed on the active layer while being opposite to the source electrode **152**. The drain electrode **154** is formed at a predetermined interval from the source electrode **152**. A channel region is defined by the source electrode **152** and drain electrode **154**.

According to one embodiment of the present invention, the source electrode **152** or drain electrode **154** may be overlapped with at least a portion of the lower gate electrode **110**, or may be overlapped with at least a portion of the upper gate electrode **175**.

The upper gate electrode **175** is formed above the etch stopper layer **135**, to thereby cover the channel region defined by the source electrode **152** and drain electrode **154**.

According to one embodiment of the present invention, if the thin film transistor substrate **100** is applied to an organic light-emitting device (OLED), the upper gate electrode **175** may be formed of an anode electrode of an organic light-emitting diode for the OLED.

The contact portion **180** electrically connects the lower gate electrode **110** with the upper gate electrode **175**. According to one embodiment of the present invention, the contact portion **180** is formed at a predetermined interval from the drain electrode **154**, wherein the contact portion **180** may be formed in an island shape. In this case, the contact portion **180** may be formed of the same material as that of the source electrode **152** or drain electrode **154**.

As mentioned above, the thin film transistor (T) according to the present invention is formed in a dual gate electrode structure where the lower gate electrode **110** is formed below the active layer, and the upper gate electrode **175** is formed above the active layer. The lower gate electrode **110** and upper gate electrode **175** of the thin film transistor (T) are electrically connected with each other through the contact portion **180**.

Hereinafter, the thin film transistor substrate according to the first embodiment of the present invention will be described in more detail with reference to FIG. 2B.

As shown in FIG. 2B, the lower gate electrode **110** is formed on the thin film transistor substrate **100**, and then a gate insulating layer **120** is formed on an entire surface of the substrate **100** including the lower gate electrode **110**.

According to one embodiment of the present invention, a first contact hole (H1) for exposing a predetermined portion

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of the lower gate electrode **110** so as to form the contact portion **180** is formed in the gate insulating layer **120**.

The active layer **130** is formed on the gate insulating layer **120**, and the etch stopper layer **135** is formed on the active layer **130**. According to one embodiment of the present invention, the active layer **130** may be formed of an oxide semiconductor.

The source electrode **152** and drain electrode **154** are formed on the etch stopper layer **135**. Also, the source electrode **152** and drain electrode **154** are formed on predetermined regions of the active layer **130**, wherein the predetermined regions indicate the regions which are not overlapped with the etch stopper layer **135**, to thereby protect the active layer **130**. Although not shown, an ohmic contact layer may be additionally interposed between the active layer **130** and the source/drain electrodes **152/154**.

A passivation layer **160** is formed on the entire surface of the substrate **100** including the source/drain electrodes **152/154**. According to one embodiment of the present invention, a second contact hole (H2) is formed in the passivation layer **160**. Through the second contact hole (H2), at least a portion of the contact portion **180** is exposed so that the contact portion **180** is brought into contact with the upper gate electrode **175**.

According to one embodiment of the present invention, the first contact hole (H1) and second contact hole (H2) may be completely overlapped with each other. In a modified embodiment of the present invention, the first contact hole (H1) and second contact hole (H2) may be partially overlapped with each other, or may not be overlapped with each other.

The upper gate electrode **175** is formed on the passivation layer **160**. The upper gate electrode **175** covers at least the channel region. Also, since the upper gate electrode **175** is filled in the second contact hole (H2), the upper gate electrode **175** is brought into contact with the contact portion **180** exposed through the second contact hole (H2), whereby the upper gate electrode **175** is electrically connected with the lower gate electrode **110**.

According to one embodiment of the present invention, a material for the upper gate electrode **175** may be different from a material for the lower gate electrode **110**. For example, the upper gate electrode **175** may be formed of a material whose transparency is higher than that of the lower gate electrode **110**.

The contact portion **180** is filled in the first contact hole (H1) formed in the gate insulating layer **120**. The contact portion **180** may be formed on predetermined portions of the gate insulating layer **120** in the periphery of the first contact hole (H1). According to one embodiment of the present invention, the contact portion **180** may be formed of the same material as those of the source/drain electrodes **152/154**.

The contact portion **180** is brought into contact with the lower gate electrode **110** exposed through the first contact hole (H1), and is simultaneously brought into contact with the upper gate electrode **175** through the second contact hole (H2), whereby the lower gate electrode **110** and upper gate electrode **175** are electrically connected with each other.

In the aforementioned embodiment of the present invention, the reason why the two contact holes (H1 and H2) are used so as to electrically connect the lower gate electrode **110** and upper gate electrode **175** with each other is that etching the plurality of layers at once is difficult. However, if each of the multiple layers is thin, or an etching technology is highly developed, it is possible to form the hole by etching the plurality of layers at once. In this case, the lower gate elec-

trode **110** and upper gate electrode **175** may be electrically connected with each other through one contact hole.

As described above, the thin film transistor (T) according to the first embodiment of the present invention is formed in the dual gate electrode structure where the lower gate electrode **110** is formed below the active layer **130**, and the upper gate electrode **175** is formed above the active layer **130**, whereby electrons drift using lower and upper surfaces of the active layer **130**.

As shown in graphs of FIGS. **3A** and **3B**, in comparison with the related art thin film transistor with the single gate electrode structure, the thin film transistor (T) with the dual gate electrode structure according to the present invention can obtain the improved output saturation characteristics. Also, it is possible to decrease a gap between transfer curves according to voltages between source and drain of the thin film transistor within a subthreshold region.

Accordingly, the thin film transistor (T) with the dual gate electrode structure according to the present invention facilitates to improve luminance uniformity of display device, current capacity and compensation capacity of thin film transistor, and to reduce power consumption.

In case of the present invention, it is possible to prevent external light from being incident on bottom and top surfaces of the thin film transistor (T) by the lower gate electrode **110** and upper gate electrode **175**, to thereby improve bias temperature stress (BTS) characteristics of the thin film transistor (T). In addition, it is possible to prevent external gas (O₂) or moisture (H₂O) from penetrating into the bottom and top surfaces of the thin film transistor (T).

In the thin film transistor (T) according to the present invention, local and global luminance uniformity may be improved, and bright dot and black dot defect may be diminished by shielding an electric field in the bottom and top surfaces of the thin film transistor (T) using the lower gate electrode **110** and upper gate electrode **175**.

Method for Manufacturing Thin Film Transistor Substrate

FIGS. **4A** to **4H** are cross sectional views illustrating a method for manufacturing the thin film transistor substrate according to the first embodiment of the present invention, which are cross sectional views along A-A' of FIG. **2A**.

First, as shown in FIG. **4A**, the lower gate electrode **110** is formed on the substrate **100**, and the gate insulating layer **120** is formed on the entire surface of the substrate **100** including the lower gate electrode **110**. Then, the active layer **130** is formed on the gate insulating layer **120**, and a material layer **135a** for forming the etch stopper layer **135** is formed on the entire surface of the substrate **100** including the active layer **130**.

As shown in FIG. **4B**, the material layer **135a** is patterned to form the etch stopper layer **135** on the active layer **130**.

As shown in FIG. **4C**, the first contact hole (H1) for exposing the lower gate electrode **110** is formed in the gate insulating layer **120**.

As shown in FIG. **4D**, a source/drain electrode layer **150a** is formed on the entire surface of the substrate **100** including the etch stopper layer **135**.

As shown in FIG. **4E**, the source/drain electrode layer **150a** is patterned, thereby forming the source electrode **152** and drain electrode **154** with a predetermined interval therebetween, and simultaneously forming the contact portion **180** inside the first contact hole (H1).

As shown in FIG. **4F**, the passivation layer **160** is formed on the entire surface of the substrate **100** including the source/drain electrodes **152/154**.

As shown in FIG. **4G**, the second contact hole (H2) for exposing the contact portion **180** is formed in the passivation layer **160**.

As shown in FIG. **4H**, the upper gate electrode **175** is formed on the passivation layer **160**. In this case, since the upper gate electrode **175** is filled in the second contact hole (H2), the upper gate electrode **175** is brought into contact with the contact portion **180**, whereby the upper gate electrode **175** is electrically connected with the lower gate electrode **110**.

Second Embodiment

In the above description for the first embodiment of the present invention, the etch stopper layer **135** is formed only in the channel region on the active layer **130**, whereby the source electrode **152** and drain electrode **154** cover all regions of the active layer **130** except the channel region.

However, in case of the second embodiment of the present invention, an etch stopper layer **135** is formed not only in the channel region but also in regions except the channel region on an active layer **130**, whereby the etch stopper layer **135** covers the active layer **130**.

Hereinafter, the thin film transistor substrate according to the second embodiment of the present invention will be described in more detail with reference to FIGS. **5** and **6**. For the following description, wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts as those of the first embodiment of the present invention.

Thin Film Transistor Substrate

FIG. **5A** is a plane view illustrating a thin film transistor substrate according to the second embodiment of the present invention. FIG. **5B** is a cross sectional view along B-B' of FIG. **5A**.

First, the thin film transistor substrate according to the second embodiment of the present invention will be described with reference to FIG. **5A**. As shown in FIG. **5A**, a thin film transistor (T) and a contact portion **180** are formed on a thin film transistor substrate **100**, wherein the thin film transistor (T) functions as a switching element for controlling an operation of each pixel, or a driving element for driving each pixel.

The thin film transistor (T) includes a lower gate electrode **110**, the etch stopper layer **135**, a source electrode **152**, a drain electrode **154**, and an upper gate electrode **175**.

The lower gate electrode **110** is formed on the thin film transistor substrate **100**. The lower gate electrode **110** is electrically connected with the upper gate electrode **175** through the contact portion **180**. The lower gate electrode **110** may be diverged from a gate line (not shown).

The etch stopper layer **135** prevents the active layer (not shown) formed thereunder from being over-etched. The etch stopper layer **135** according to the second embodiment of the present invention is formed on an entire surface of the substrate **100** including the lower gate electrode **110**. In a modified embodiment of the present invention, the etch stopper layer **135** may be formed on a predetermined region of the substrate **100**. For example, the etch stopper layer **135** may be formed on at least one of a first region and a second region of the substrate **100**, wherein the first region may include the thin film transistor region and a line region, and the second region may include a region provided with a storage capacitor.

In order to bring the source electrode **152** and drain electrode **154** into contact with the active layer **130**, as shown in FIG. **5A**, third contact hole (H3) and fourth contact hole (H4) are formed in the etch stopper layer **135**. For example, the source electrode **152** and active layer **130** are brought into

contact with each other through the third contact hole (H3), and the drain electrode 154 and active layer 130 are brought into contact with each other through the fourth contact hole (H4).

The source electrode 152 is connected with a data line 150, and more particularly, the source electrode 152 may be diverged from the data line 150. The drain electrode 154 is formed on the active layer while being opposite to the source electrode 152, wherein the drain electrode 154 is formed at a predetermined interval from the source electrode 152. A channel region is defined by the source electrode 152 and drain electrode 154.

According to one embodiment of the present invention, the source electrode 152 or drain electrode 154 may be overlapped with at least a portion of the lower gate electrode 110, or may be overlapped with at least a portion of the upper gate electrode 175.

The upper gate electrode 175 is formed above the etch stopper layer 135, to thereby cover the channel region defined by the source electrode 152 and drain electrode 154.

According to one embodiment of the present invention, if the thin film transistor substrate 100 is applied to an organic light emitting device (OLED), the upper gate electrode 175 may be formed of an anode electrode of an organic light emitting diode for the OLED.

The contact portion 180 electrically connects the lower gate electrode 110 with the upper gate electrode 175. In the

135. For example, the source electrode 152 and active layer 130 are brought into contact with each other through the third contact hole (H3), and the drain electrode 154 and active layer 130 are brought into contact with each other through the fourth contact hole (H4).

In case of the thin film transistor (T) according to the first embodiment of the present invention, the source/drain electrodes 152/154 cover all regions of the active layer 130 except the channel region, whereby the overlap area between the source/drain electrodes 152/154 and the lower gate electrode 110 is increased in size. However, in case of the second embodiment of the present invention, the etch stopper layer 135 is formed on the entire surface of the substrate 100, whereby the etch stopper layer 135 covers all regions of the active layer 130 except the contact region between the source/drain electrodes 152/154 and the active layer 130.

Thus, in comparison with the first embodiment of the present invention, the second embodiment of the present invention is provided with the decreased overlap area between the lower gate electrode 110 and the source/drain electrodes 152/154. As shown in the following Table 1, when the thin film transistor (T) is turned-on/off, a capacitance of the thin film transistor (T) according to the second embodiment of the present invention is reduced largely in comparison with the first embodiment of the present invention.

TABLE 1

kind	Completion value	First embodiment		Second embodiment		Off cap ratio	On cap ratio
		Off cap	On cap	Off cap	On cap	First embodiment/ Second embodiment (%)	First embodiment/ Second embodiment (%)
Sw. TFT	5/11.4	14.2	33.15	11.15	26.8	79%	82%
Sc. TFT	10/11.4	20.5	50.45	16.14	41.27	79%	82%
Dr. TFT	100/11.4	CGS 141.2 CGD 53.3	288	CGS 109 CGD 53.3	256.33	CGS 77% CGD The same	89%

same manner as the first embodiment of the present invention, the contact portion 180 is formed at a predetermined interval from the drain electrode 154, wherein the contact portion 180 may be formed in an island shape. In this case, the contact portion 180 may be formed of the same material as that of the source electrode 152 or drain electrode 154.

Hereinafter, the thin film transistor substrate according to the second embodiment of the present invention will be described in more detail with reference to FIG. 5B.

As shown in FIG. 5B, the lower gate electrode 110 is formed on the thin film transistor substrate 100, and then a gate insulating layer 120 is formed on the entire surface of the substrate 100 including the lower gate electrode 110 (for example, the thin film transistor region and the line region except a region on which the storage capacitor is formed of the substrate 100). Then, the active layer 130 is formed on the gate insulating layer 120. According to one embodiment of the present invention, the active layer 130 may be formed of an oxide semiconductor.

The etch stopper layer 135 is formed on the entire surface of the substrate 100 including the active layer 130, as mentioned above. In this case, the third contact hole (H3) and fourth contact hole (H4) are formed in the etch stopper layer

Also, the contact region between the active layer 130 and the source/drain electrodes 152/154 is determined based on a design rule of the etch stopper layer 135, whereby an overlay rule of the active layer 130 and the source/drain electrodes 152/154 has no influence on the left direction (for example, the direction facing from the drain electrode toward the source electrode in FIG. 5B) and the right direction (for example, the direction facing from the source electrode toward the drain electrode in FIG. 5B).

Also, if the active layer 130 is formed of the oxide semiconductor, passivation of the active layer 130 has a large influence on reliability of the thin film transistor (T). In case of the second embodiment of the present invention, the etch stopper layer 135 protects not only channel region but also all regions of the active layer 130 except the contact region between the active layer 130 and the source/drain electrodes 152/154, whereby reliability of the thin film transistor (T) may be improved.

As mentioned above, a parasitic capacitance of the thin film transistor (T) is minimized owing to the structure of the etch stopper layer 135, to thereby reduce a line resistance.

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For forming the contact portion **180**, a first contact hole (H1) for exposing a predetermined portion of the lower gate electrode **110** is formed in the gate insulating layer **120** and etch stopper layer **135**.

The source/drain electrodes **152/154** are formed on the etch stopper layer **135**. As mentioned above, the source/drain electrodes **152/154** are brought into contact with the active layer **130** through the third and fourth contact holes (H3, H4). Although not shown, an ohmic contact layer may be additionally interposed between the active layer **130** and the source/drain electrodes **152/154**.

A passivation layer **160** is formed on the entire surface of the substrate **100** including the source/drain electrodes **152/154**. Then, a second contact hole (H2) for exposing at least a portion of the contact portion **180** is formed in the passivation layer **160**, to thereby bring the contact portion **180** into contact with the upper gate electrode **175**.

The first contact hole (H1) and second contact hole (H2) may be completely overlapped with each other. According to a modified embodiment of the present invention, the first contact hole (H1) and second contact hole (H2) may be partially overlapped with each other, or may not be overlapped with each other.

The upper gate electrode **175** is formed on the passivation layer **160**, wherein the upper gate electrode **175** covers at least the channel region. Also, since the upper gate electrode **175** is filled in the second contact hole (H2), the upper gate electrode **175** is brought into contact with the contact portion **180** exposed through the second contact hole (H2), whereby the upper gate electrode **175** is electrically connected with the lower gate electrode **110**.

According to one embodiment of the present invention, a material for the upper gate electrode **175** may be different from a material for the lower gate electrode **110**. For example, the upper gate electrode **175** may be formed of a material whose transparency is higher than that of the lower gate electrode **110**.

The contact portion **180** is formed inside the first contact hole (H1) formed in the gate insulating layer **120** and etch stopper layer **135**. The contact portion **180** may be formed not only inside the first contact hole (H1) but also on predetermined portions of the etch stopper layer **135** in the periphery of the first contact hole (H1). According to one embodiment of the present invention, the contact portion **180** may be formed of the same material as those of the source/drain electrodes **152/154**. The contact portion **180** is brought into contact with the lower gate electrode **110** exposed through the first contact hole (H1), and is simultaneously brought into contact with the upper gate electrode **175** exposed through the second contact hole (H2), whereby the lower gate electrode **110** and upper gate electrode **175** are electrically connected with each other.

In the aforementioned embodiment of the present invention, the reason why the two contact holes (H1 and H2) are used so as to electrically connect the lower gate electrode **110** and upper gate electrode **175** with each other is that etching the plurality of layers at once is difficult. However, if each of the multiple layers is thin, or an etching technology is highly developed, it is possible to form the hole by etching the plurality of layers at once. In this case, the lower gate electrode **110** and upper gate electrode **175** may be electrically connected with each other through one contact hole.

As mentioned above, the thin film transistor (T) according to the second embodiment of the present invention is formed in a dual gate electrode structure, and the etch stopper layer **135** is formed on the entire surface of the substrate **110**. Thus, the thin film transistor (T) according to the second embodi-

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ment of the present invention enables to have efficiency of the thin film transistor (T) of the dual gate electrode structure disclosed in the first embodiment of the present invention, and also to reduce the line resistance and capacitance of thin film transistor (T).

Method for Manufacturing Thin Film Transistor Substrate

FIGS. **6A** to **6H** are cross sectional views illustrating a method for manufacturing the thin film transistor substrate according to the second embodiment of the present invention, which are cross sectional views along B-B' of FIG. **5A**.

First, as shown in FIG. **6A**, the lower gate electrode **110** is formed on the substrate **100**, and the gate insulating layer **120** is formed on the entire surface of the substrate **100** including the lower gate electrode **110**. Then, the active layer **130** is formed on the gate insulating layer **120**, and a material layer **135a** for forming the etch stopper layer **135** is formed on the entire surface of the substrate **100** including the active layer **130**.

As shown in FIG. **6B**, the material layer **135a** is patterned to form the etch stopper layer **135** including the third and fourth contact holes (H3, H4) for exposing the active layer **130**.

As shown in FIG. **6C**, the first contact hole (H1) for exposing the lower gate electrode **110** is formed by patterning the gate insulating layer **120** and etch stopper layer **135**.

In FIGS. **6B** and **6C**, the process for forming the third and fourth contact holes (H3, H4) and the process for forming the first contact hole (H1) are performed separately. According to a modified embodiment of the present invention, the process for forming the third and fourth contact holes (H3, H4) and the process for forming the first contact hole (H1) may be performed through single etching process.

Then, as shown in FIG. **6D**, a source/drain electrode layer **150a** is formed on the entire surface of the substrate **100** including the etch stopper layer **135**.

As shown in FIG. **6E**, the source/drain electrode layer **150a** is patterned, thereby forming the source electrode **152** and drain electrode **154** with a predetermined interval therebetween, and simultaneously forming the contact portion **180** inside the first contact hole (H1). Accordingly, the source electrode **152** is brought into contact with the active layer **130** through the third contact hole (H3), and the drain electrode **154** is brought into contact with the active layer **130** through the fourth contact hole (H4).

As shown in FIG. **6F**, the passivation layer **160** is formed on the entire surface of the substrate **100** including the source/drain electrodes **152/154**.

As shown in FIG. **6G**, the second contact hole (H2) for exposing the contact portion **180** is formed in the passivation layer **160**.

As shown in FIG. **6H**, the upper gate electrode **175** is formed on the passivation layer **160**. In this case, since the upper gate electrode **175** is filled in the second contact hole (H2), the upper gate electrode **175** is brought into contact with the contact portion **180**, whereby the upper gate electrode **175** is electrically connected with the lower gate electrode **110**.

First Modified Embodiment

In the above first and second embodiments of the present invention, the contact portion **180** for electrically connecting the lower gate electrode **110** and upper gate electrode **175** of the thin film transistor (T1) is formed in the island shape. However, according to the first modified embodiment of the present invention, as shown in FIGS. **7A** and **7B**, a contact

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portion **180** may be formed as a single body with a source electrode or drain electrode (S or D) of a thin film transistor (T2).

Also, in the above first and second embodiments of the present invention, the source electrode **152** is connected with the data line **150**. However, according to the first modified embodiment of the present invention, a source electrode **152** may be connected with a power line.

Second Modified Embodiment

If the thin film transistor substrate **100** according to the aforementioned embodiment of the present invention is applied to a bottom emission type OLED, as shown in FIG. **8**, a connection electrode **176** is formed on a passivation layer **160**, wherein the connection electrode **176** is provided at a predetermined interval from an upper gate electrode **175**. On the connection electrode **176**, there are a color filter layer **800**, a planarization layer **810**, and passivation layer **820** formed sequentially. Then, a pixel electrode **830** is additionally formed on the passivation layer **820**, wherein the pixel electrode **830** functions as an anode electrode of a light emitting device.

In this case, the connection electrode **176** is formed of the same material as that of the upper gate electrode **175**, and the connection electrode **176** is formed together with the upper gate electrode **175**.

Through the connection electrode **176**, the pixel electrode **830** may be electrically connected with the source or drain electrode **152** or **154**. In more detail, as shown in FIG. **8**, the connection electrode **176** is brought into contact with the source or drain electrode **152** or **154** through a fifth contact hole (H5) formed in the passivation layer **160**; and the pixel electrode **830** is brought into contact with the connection electrode **176** through a sixth contact hole (H6) formed in the planarization layer **810** and passivation layer **820**, whereby the pixel electrode **830** is electrically connected with the source or drain electrode **152** or **154**.

This structure reduces a contact resistance by preventing oxidation of the source/drain electrodes **152/154**, and also increases a capacitance of the thin film transistor substrate because a dual or triple capacitor is provided by additionally forming the connection electrode **176** between the lower gate electrode **110** and the pixel electrode **830**, wherein the connection electrode **176** is formed of the same material as that of the upper gate electrode **175**.

For convenience of explanation, FIG. **8** illustrates that the thin film transistor (T) has the structure shown in the second embodiment of the present invention. However, the thin film transistor (T) of FIG. **8** may have the structure shown in the first embodiment of the present invention.

Third Modified Embodiment

In the above embodiments of the present invention, one contact portion is formed for each thin film transistor on the thin film transistor substrate. However, in case of the third modified embodiment of the present invention, as shown in FIGS. **9A** and **9B**, a thin film transistor substrate may be provided in such a manner that two thin film transistors use one contact portion in common.

In more detail, as shown in FIG. **9**, if the first thin film transistor (T1) and second thin film transistor (T2) use one lower gate electrode **110** in common, upper gate electrodes **175** of the first thin film transistor (T1) and second thin film transistor (T2) are formed as a single body, both the electric connection between the lower gate electrode **110** and upper

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gate electrode **175** of the first thin film transistor (T1) and the electric connection between the lower gate electrode **110** and upper gate electrode **175** of the second thin film transistor (T2) may be realized through the use of one contact portion **180**.

In this case, as mentioned above, the contact portion **180** may be formed in an island shape.

Organic Light Emitting Device (OLED)

If the thin film transistor substrate according to the above embodiment of the present invention is applied to an OLED, the thin film transistors shown in FIGS. **2A/2B** and FIGS. **3A/3B** may be used as one or more switching thin film transistors constituting the OLED. Also, thin film transistors shown in FIGS. **7A** and **7B** may be used as driving thin film transistors constituting the OLED.

If the OLED includes two or more switching thin film transistors, at least two thin film transistors may electrically connect lower and upper gate electrodes with each other through the use of common contact portion shown in FIGS. **9A** and **9B**.

Also, in case of a storage capacitor for the OLED, it may be formed in a structure shown in FIG. **10**.

In more detail, as shown in FIG. **10**, a lower gate electrode **110**, a gate insulating layer **120**, an etch stopper layer **135** are sequentially formed on a substrate **100**. Then, a seventh contact hole (H7) for exposing the lower gate electrode **110** is formed in the gate insulating layer **120** and etch stopper layer **135**.

In this case, a contact portion **1080** is filled in the seventh contact hole (H7), wherein the contact portion **1080** is formed of the same material as those of source/drain electrodes (not shown).

Also, a passivation layer **160** is formed on the etch stopper layer **135**, and an eighth contact hole (H8) for exposing the contact portion **1080** is formed in the passivation layer **160**.

On the passivation layer **160**, there is an upper gate electrode **175**. According as the upper gate electrode **175** is filled in the eighth contact hole (H8), the upper gate electrode **175** is brought into contact with the contact portion **1080**, whereby the upper gate electrode **175** is electrically connected with the lower gate electrode **110**.

Also, a pixel electrode **1090** is formed on the upper gate electrode **175**. According to one embodiment of the present invention, the pixel electrode **1090** may be formed of the same material as that of an anode electrode of an organic light emitting diode.

In the above embodiments of the present invention, the etch stopper layers are necessarily included. However, in case of modified embodiments of the present invention, the etch stopper layer may be omitted. In this case, the source and drain electrodes may be directly formed on the active layer.

According to the present invention, the lower gate electrode **110** is formed below the active layer **130**, and the upper gate electrode **175** is formed above the active layer **130**, whereby the electrons drift through both the lower and upper surfaces of the active layer **130**, thereby achieving the output saturation characteristics, and, decreasing a gap between transfer curves according to voltages between source and drain of the thin film transistor within a subthreshold region.

According to the present invention, owing to the improved output and transfer characteristics of the thin film transistor, it is possible to improve luminance uniformity of display device, current capacity of thin film transistor and compensation capacity, and to reduce the power consumption.

According to the present invention, it is possible to prevent external light from being incident on the bottom and top surfaces of the thin film transistor (T) by the lower gate

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electrode **110** and upper gate electrode **175**, to thereby improve bias temperature stress (BTS) characteristics of the thin film transistor (T). In addition, it is possible to prevent external gas (O₂) or moisture (H₂O) from penetrating into the bottom and top surfaces of the thin film transistor (T).

According to the present invention, the local and global luminance uniformity may be improved, and bright dot and black dot defect may be diminished by shielding the electric field in the bottom and top surfaces of the thin film transistor (T) using the lower gate electrode **110** and upper gate electrode **175**.

According to the present invention, the upper gate electrode **175** is positioned between the pixel electrode **830** and the source/drain electrodes **152/154**, to thereby reduce the contact resistance by preventing oxidation of the source/drain electrodes **152/154**.

According to the present invention, the dual or triple capacitor is provided by additionally forming the upper gate electrode **175** between the lower gate electrode **110** and the pixel electrode **830**, to increase the capacitance of the thin film transistor substrate

According to the present invention, the etch stopper layer **135** is formed on the thin film transistor region and the line region except the storage capacitor, and then the etch stopper layer **135** is patterned based on the minimum design rule for the contact between the active layer **130** and the source/drain electrodes **152/154**, so that it is possible to decrease the overlap area between the gate electrode and the source/drain electrodes **152/154**. Thus, the capacitance of thin film transistor according to the present invention is reduced when the thin film transistor is turned-on/off.

According to the present invention, the etch stopper layer **135** is formed at left and right sides of the channel region on the active layer **130**, whereby the active layer **130** is protected by the etch stopper layer **135**.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the inventions. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method for manufacturing a thin film transistor substrate comprising:

sequentially forming a lower gate electrode of a thin film transistor of an organic light emitting device (OLED) pixel, a gate insulating layer, and an active layer on a substrate;

forming a first contact hole by patterning the gate insulating layer to expose the lower gate electrode;

forming a source/drain electrode layer on the active layer;

forming a source electrode of the thin film transistor of the OLED pixel, a drain electrode of the thin film transistor of the OLED pixel, and a contact portion by patterning the source/drain electrode layer, wherein the contact portion is brought into contact with the lower gate electrode through the first contact hole;

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forming a passivation layer on an entire surface of the substrate including the source electrode, drain electrode, and contact portion;

forming a second contact hole by patterning the passivation layer to expose the contact portion; and

forming an upper gate electrode on the passivation layer, wherein the upper gate electrode covers a channel region defined by the source electrode and the drain electrode, and the upper gate electrode is brought into contact with the contact portion through the second contact hole.

2. The method according to claim 1, further comprising forming an etch stopper layer on the active layer before forming the first contact hole.

3. The method according to claim 2, wherein the etch stopper layer is formed on an entire surface of the substrate including the active layer.

4. The method according to claim 1, wherein the contact portion is formed in an island shape, or is formed as a single body with the source electrode or drain electrode of another thin film transistor.

5. The method according to claim 1, further comprising forming an organic light emitting device of the OLED pixel coupled to the thin film transistor.

6. The method according to claim 1, further comprising forming a connection electrode electrically connected to the source electrode of the thin film transistor.

7. The method according to claim 6, wherein the connection electrode is formed in a same layer as the upper gate electrode.

8. The method according to claim 6, further comprising forming a pixel electrode electrically connected to the connection electrode.

9. The method according to claim 6, further comprising forming a color filter over the connection electrode and forming a pixel electrode over the color filter, the pixel electrode electrically connected to the connection electrode.

10. The method according to claim 6, wherein the connection electrode is in direct contact with the source electrode of the thin film transistor.

11. The method according to claim 6, wherein the connection electrode is formed of a same material as that of the upper gate electrode.

12. The method according to claim 6, wherein the connection electrode and the upper gate electrode are formed using a single patterning process.

13. The method according to claim 6, wherein the connection electrode is formed at a predetermined interval from the upper gate electrode on the passivation layer.

14. The method according to claim 1, wherein the first contact hole and the second contact hole are not overlapped with each other.

15. The method according to claim 1, wherein the lower gate electrode and the upper gate electrode are formed of different materials.

16. The method according to claim 1, wherein the upper gate electrode is formed of a material whose transparency is higher than that of the lower gate electrode.

17. The method according to claim 1, wherein the active layer is formed of an oxide semiconductor.

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